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# Artificial Intelligence in Oncology and Cardiovascular Treatment: Challenges and Opportunities for Precision Healthcare

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## Abstract

Artificial Intelligence (AI) is transforming precision medicine, particularly in oncology and cardiovascular (CV) treatment, by enabling more accurate diagnoses, personalized treatments, and improved patient outcomes. The objective of this study is to explore the role and perceptions of Artificial Intelligence (AI) in Oncology and Cardiovascular (CV) treatment challenges and opportunities for precision healthcare management, focusing on its effectiveness in enhancing patient safety, reducing errors, and optimizing treatment. We conducted a systematic review in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

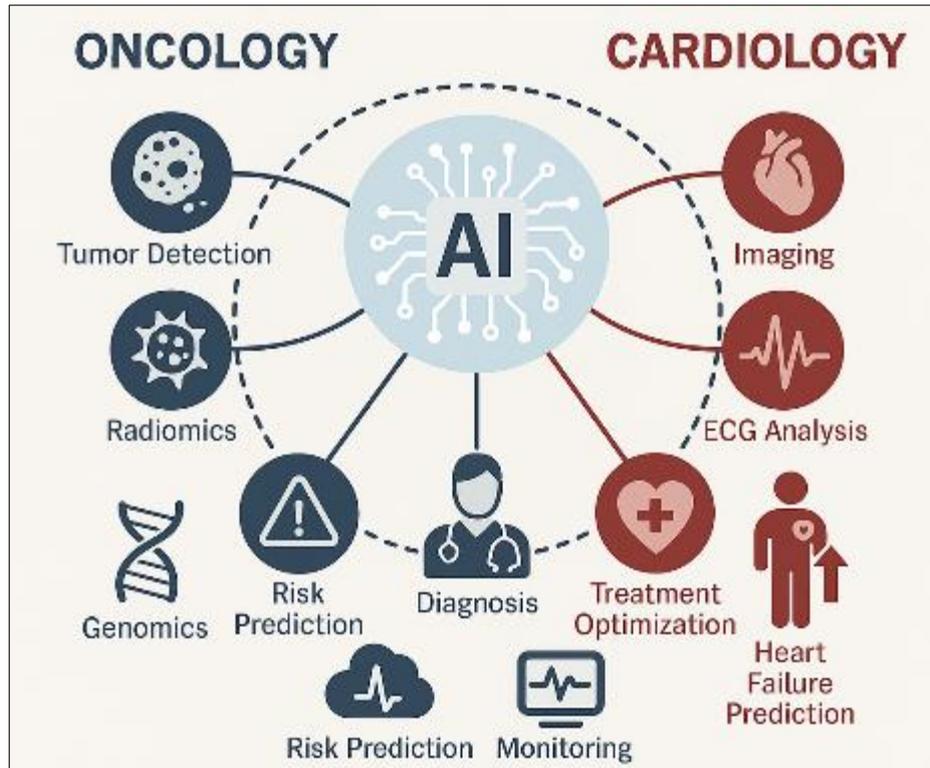
This systematic review aimed to synthesize the literature on AI in healthcare. To identify relevant articles, we conducted comprehensive searches in PubMed, Google Scholar, Web of Science, Scopus and ScienceDirect in September 2025 using targeted search terms, including "AI applications", "opportunities" and "future challenges". By aggregating and analyzing large volumes of data and applying them to clinical tasks through various algorithms and models, AI plays a pivotal role in advancing precision medicine, particularly in the fields of cardiology and oncology. In this study, we outline the future opportunities for AI use in Oncology and Cardiovascular medicine. This review aims to provide valuable resources to clinicians and researchers and encourage further investigation in this field.

**Keywords:** Artificial Intelligence; Oncology; Cardiology; Cardiovascular Diseases (CVDs); Personalized Medicine

## 1. Introduction

Artificial Intelligence (AI) is poised to redefine the standards of care in two of medicine's most formidable frontiers: oncology and cardiovascular disease. The convergence of massive biomedical data and sophisticated AI algorithms is creating a paradigm shift, moving us decisively from population-based guidelines to truly personalized, predictive healthcare. This review delves into the specific challenges and opportunities presented by AI in the pursuit of this precision vision.

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**Figure 1** An overview of Artificial Intelligence (AI) in Oncology and Cardiology

AI tools and technologies are playing an increasingly active role in modern healthcare innovation, impacting diagnosis, treatment recommendations, treatment plan design and delivery, prediction of epidemic conditions, and hospital management [1]. One area where AI is particularly impactful is in oncology, where it offers innovative approaches for research and treatment of cancer, a leading cause of mortality worldwide [2]. AI has emerged as a powerful tool in oncology, capable of revolutionizing cancer diagnosis, treatment, and management through early detection, personalized treatment strategies, and drug discovery [3]. AI algorithms have demonstrated the capability to improve early cancer detection rates by 20–30% [4].

Simultaneously, the field of cardio-oncology has emerged as a critical interdisciplinary area addressing the intersection of cardiovascular diseases (CVD) and cancer [5]. Cardiovascular disease is a leading cause of death among cancer survivors [6]. Cardio-oncology focuses on the prevention and management of cardiovascular consequences resulting from cancer therapies [7]. This includes using imaging, electronic health records (EHRs), electrocardiograms (ECGs), and multi-omics data for early cardiotoxicity detection, risk stratification, and long-term risk prediction [8]. AI also has the potential to improve cancer survivor prediction, early diagnosis, and ultimately prevention of cardiovascular issues [9].

Precision healthcare, which intends to adopt prevention, diagnosis, and treatment based on individual characteristics, is a key concept in both oncology and cardiology [10]. This approach considers individual variability in genes, environment, and lifestyle [11]. The effectiveness of precision medicine relies heavily on well-established biomarkers, functional tests, and imaging techniques [12]. While precision medicine has gained significant popularity in oncology, particularly with advancements in genomics and AI [13]. Precision cardio-oncology is a necessary concept that considers the cardiovascular risk, oncologic treatment, and overall diagnosis for cancer patients [14].

However, the widespread implementation of AI in healthcare, particularly in precision cardio-oncology, faces several challenges [15]. These include issues with data security, privacy, potential biases in algorithms, and limited diversity in research participant pools [16]. There are also challenges related to data quality, algorithmic biases, and clinical validation that limit widespread adoption [17]. Despite these challenges, the integration of AI with precision medicine offers substantial opportunities to enhance and advance patient care, remote monitoring, and the overall understanding of complex diseases [18]. This review will explore the current landscape of AI applications in oncology and cardiovascular treatment, highlighting both the opportunities they present for precision healthcare and the significant challenges that must be addressed for their successful and equitable implementation [19].

## 2. Materials and Method

The methodology involved a comprehensive literature search across various databases to identify relevant research on AI in oncology and cardiovascular health care. The literature search was conducted in PubMed, Google Scholar, Web of Science, Scopus and ScienceDirect.

Keywords related to "AI in oncology treatment review paper methodology," "AI in cardiovascular treatment review paper methodology," and "precision healthcare challenges and opportunities review paper methodology" were used to gather a broad range of studies.

The inclusion criteria targeted studies that explored AI applications in oncology and cardiovascular treatment, highlighting both the opportunities they present for precision healthcare and the significant challenges in cardio-oncology, focusing on cardiovascular risk prediction, monitoring, and management.

### 2.1. Data Extraction and Synthesis

Information was extracted from the selected articles, with a focus on the specific AI techniques employed, their applications, reported outcomes, and identified challenges within oncology and cardiovascular treatment. Key data points included details on AI's impact on diagnosis, treatment recommendations, treatment plan design and delivery, prediction of epidemic conditions, and hospital management. Particular attention was given to studies that addressed the intersection of cardiovascular diseases and cancer, including the use of imaging, electronic health records (EHRs), electrocardiograms (ECGs), and multi-omics data for personalized precision healthcare. The synthesis of data also considered how AI contributes to real-time monitoring and personalized medicine.

### 2.2. Artificial Intelligence (AI) in Oncology

AI has emerged as a powerful tool with the potential to revolutionize cancer diagnosis, treatment, and management [20]. It integrates and synthesizes vast amounts of multi-dimensional data to deduce patterns and predict outcomes, ultimately improving decision-making for both patients and clinicians. A visual roadmap of Artificial Intelligence (AI) in Oncology is presented in Figure: 2

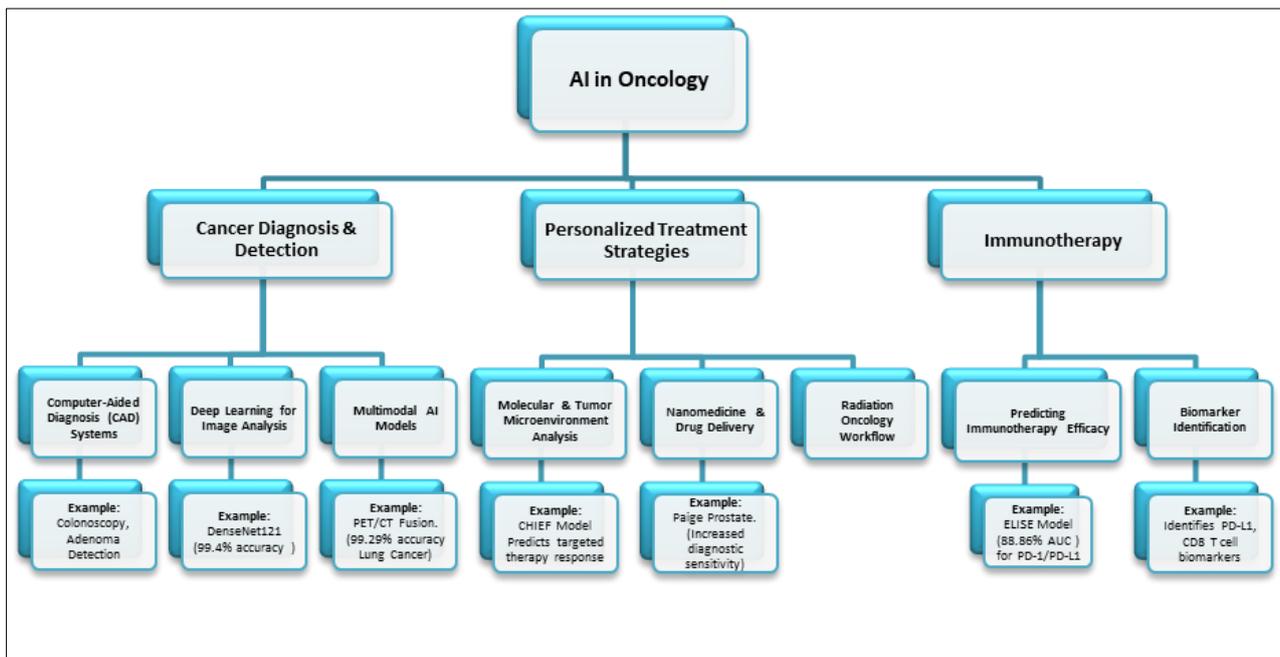


Figure 2 Artificial Intelligence (AI) in Oncology

### 2.3. Cancer Diagnosis and Detection

AI plays a crucial role in improving the accuracy and efficiency of cancer diagnosis and detection.

### *2.3.1. Computer-Aided Diagnosis (CAD)*

CAD systems enhance the diagnostic process by assisting physicians in the detection, characterization, and monitoring of tumors through quantitative analysis of suspicious lesions. These systems have been shown to improve the accuracy and efficiency of medical image interpretation, for instance, by enhancing adenoma detection during colonoscopy.

### *2.3.2. Deep Learning in Imaging*

Deep learning models, particularly convolutional neural networks (CNNs), are highly effective in medical image analysis, often outperforming traditional diagnostic methods. For example, CNNs can differentiate between benign and malignant lung cancer tissue with 96.07% accuracy, while a DenseNet121 model achieved 99.4% accuracy in classifying seven common cancer types.

### *2.3.3. Multi-modal Data Integration*

AI models can integrate various data sources, including imaging, histology, genomics, and electronic health records, to provide a more comprehensive understanding of a patient's condition and improve diagnostic and prognostic accuracy[21]. The fusion of PET and CT scans has demonstrated superior accuracy in lung tumor detection, reaching 99.29%.

## **2.4. Treatment Planning and Personalization**

AI contributes significantly to personalized medicine by tailoring treatment strategies to individual patient characteristics and predicting treatment responses [21].

### *2.4.1. Molecular Profiling and TME Analysis*

AI-driven models integrate metabolomics data, genomic sequencing, and imaging to effectively characterize molecular profiles, offering critical insights into tumor behavior and progression. The Clinical Histopathology Imaging Evaluation Foundation (CHIEF) model helps identify key genetic mutations and predicts tumor responses to targeted therapies.

### *2.4.2. Nano medicine and Drug Delivery*

AI is advancing Nano medicine and Nano-oncology by optimizing drug delivery systems and improving real-time patient monitoring. Machine learning models can predict drug delivery kinetics and optimize Nano carrier properties, which helps reduce systemic toxicity and improves patient outcomes. For instance, the FDA-approved Paige Prostate model enhanced pathologists' diagnostic sensitivity for prostate cancer from 74% to 90%.

### *2.4.3. Radiation Oncology*

AI has diverse applications throughout the radiation oncology workflow, with the potential to improve the precision, efficiency, and outcomes of radiation therapy. This includes optimizing treatment planning, enhancing image analysis for tumor detection and segmentation, facilitating adaptive radiation therapy (ART), and enabling predictive analytics to guide clinical decision-making.

## **2.5. Immunotherapy**

AI supports immunotherapeutic interventions by stimulating or modifying the host immune system to destroy malignant cells.

### *2.5.1. Predicting Immunotherapy Efficacy*

Neural networks are used to predict peptide binding affinity for neoantigen recognition and to design personalized antibodies. The ELISE model, which combines neural networks with patient data, achieved an 88.86% AUC in predicting the efficacy of PD-1/PD-L1 inhibitors in metastatic urothelial cancer.

### *2.5.2. Biomarker Identification*

Machine learning algorithms analyze gene expression and immune microenvironment biomarkers to identify predictive markers for immune checkpoint inhibitors (ICIs). AI also assists in peripheral immune cell profiling to identify predictive biomarkers, such as PD-L1 expression on monocytes and CD8 T cells, which are critical for treatment decisions.

## **2.6. Opportunities for AI in Oncology**

AI is reshaping the landscape of oncology, offering new and important opportunities to improve cancer patient management.

### *2.6.1. Enhanced Diagnostics and Early Detection*

AI applications are improving early cancer detection, often with higher sensitivity and specificity than traditional methods, leading to earlier diagnoses and better patient outcomes. This is particularly evident in diagnostic imaging, where AI can significantly reduce manual steps for lesion detection and segmentation, providing more standardized and accurate results [22].

### *2.6.2. Personalized Treatment and Prognosis*

AI models can generate more accurate predictive and prognostic models, aiding in personalized medicine by forecasting individual responses to treatment and predicting disease progression. Multimodal analysis, integrating various data types, helps in better risk stratification and treatment selection, leading to more precise therapies [21].

### *2.6.3. Accelerated Drug Discovery*

AI can expedite drug discovery and development by identifying optimal Nano carrier compositions, predicting drug interactions, and optimizing multi-drug regimens. AI frameworks like DeepDR and SNF-CVAE enhance drug repurposing, reducing development costs and accelerating clinical translation.

### *2.6.4. Improved Health Equity*

AI has the potential to reduce healthcare disparities and address both biological and social determinants of health (SDOH). For example, AI can predict financial toxicity in cancer patients, enabling healthcare providers to offer timely interventions such as financial counseling or adjustments to treatment plans.

### *2.6.5. Streamlined Clinical Workflows*

AI can enhance efficiency and quality in areas such as radiation oncology by automating tasks and providing decision support. AI also offers opportunities in clinical trials for patient recruitment, trial design, and data management.

## **2.7. Challenges for AI in Oncology**

Despite its promising potential, the widespread adoption of AI in oncology faces several significant challenges [23].

### *2.7.1. Data Quality and Quantity*

AI models require large volumes of high-quality, diverse, and well-annotated data for effective training and validation. Challenges include ensuring data quality, achieving interoperability and standardization across various data sources, and addressing resource limitations that can lead to gaps in patient data documentation [24]. The generalizability of AI models across different populations and healthcare settings remains a significant hurdle [22].

### *2.7.2. Algorithmic Bias and Fairness*

AI technologies can exhibit bias, potentially leading to unequal healthcare allocation and exacerbating existing health disparities. Addressing this requires rigorous audits of training data, the development of bias-correction algorithms, and transparent decision-making frameworks to ensure fair and equitable outcomes for all patients [21].

### *2.7.3. Model Interpretability and Transparency*

Many deep learning models are often considered "black boxes," making it difficult to interpret their predictions and understand the underlying rationale for their decisions. Improving AI explainability is crucial for building trust among clinicians and patients and for facilitating clinical adoption, especially in high-stakes areas like oncology.

### *2.7.4. Clinical Validation and Integration*

Most AI applications in oncology require rigorous validation for reproducibility and generalizability across diverse clinical settings. Integrating AI tools into existing clinical workflows can be complex, necessitating changes in practice patterns and addressing potential concerns about workflow disruption.

2.7.5. Regulatory and Ethical Considerations

The rapid advancement of AI demands clear regulatory frameworks and ethical guidelines to ensure patient safety, data privacy, and accountability [25]. The use of sensitive health data for research into social determinants of health (SDOH) raises particular privacy concerns.

2.7.6. Cost and Accessibility

The high costs associated with developing and deploying AI-driven solutions, coupled with the need for specialized expertise, can hinder accessibility and scalability, particularly in resource-limited settings.

2.8. Artificial Intelligence (AI) in Cardiovascular Diseases(CVDs)

AI is changing clinical practice in cardiology by handling large amounts of clinical, biological, and imaging data to improve diagnostic accuracy and tailor treatments [26]. AI applications broadly apply to multimodal cardiac imaging, including echocardiography, cardiac CT, and cardiac MRI [27]. A visual roadmap of Artificial Intelligence (AI) in Cardiology is presented in Figure: 3

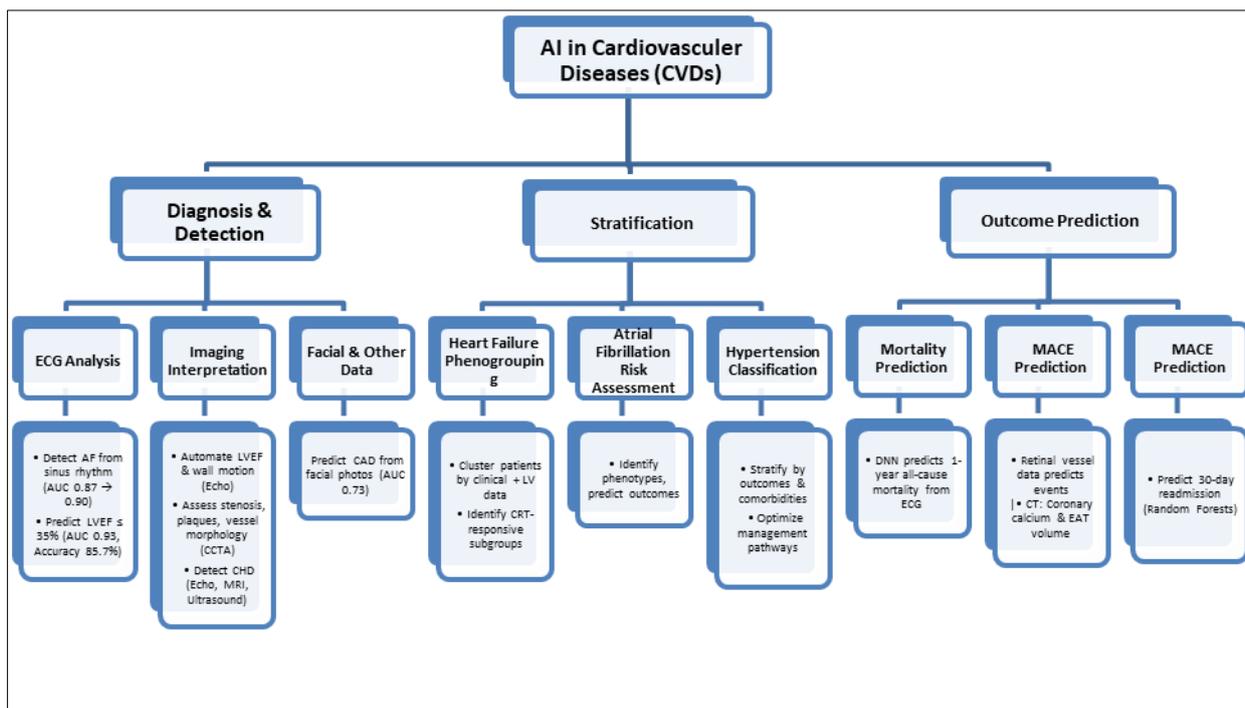


Figure 3 Artificial Intelligence (AI) in Cardiovascular Disease(CVD)

2.9. Cardiovascular Disease Diagnosis and Detection

AI algorithms are being used to improve the diagnosis of various CVDs, leveraging different data modalities [28].

2.9.1. Electrocardiography (ECG) Analysis

AI-powered ECGs (AI-ECGs) can detect subtle patterns in ECG waveforms that clinicians might miss, aiding in the diagnosis of conditions like heart failure, atrial fibrillation (AF), hypertrophic cardiomyopathy (HCM), and valvular heart disease[28], [29]. For example, a deep learning (DL) model identified AF from normal sinus rhythm ECGs with an AUC of 0.87, which improved to 0.90 over a follow-up period. AI-ECG can also predict ventricular dysfunction with an AUC of 0.93 and an accuracy of 85.7%.

2.9.2. Cardiac Imaging Interpretation

AI enhances the effectiveness of auxiliary tools such as CT, echocardiography, and magnetic resonance imaging (MRI). AI-driven systems can automate tasks like quantifying left ventricular ejection fraction (LVEF) from echocardiograms with accuracy comparable to clinicians. In coronary computed tomography angiography (CCTA), AI algorithms can

rapidly and accurately assess stenosis, atherosclerosis, and vessel morphology. AI also helps detect congenital heart disease (CHD) by identifying abnormal image frames in echocardiographic and screening ultrasound images [29].

### *2.9.3. Prediction of Disease from Diverse Data*

AI can even identify certain diseases from facial features, enabling rapid screening of large populations. For instance, a DL algorithm detected coronary artery disease (CAD) from face photos with an AUC of 0.73.

## **2.10. Disease Stratification**

AI provides novel approaches for more accurate stratification and typing of CVD patients, which is crucial for personalized medicine [29].

### *2.10.1. Heart Failure (HF) Phenogrouping*

AI algorithms can categorize patients with HF based on clinical parameters and left ventricular data, identifying phenogroups with differential responses to therapies like cardiac resynchronization therapy (CRT).

### *2.10.2. Atrial Fibrillation (AF) Risk Assessment*

AI can identify clinical phenotypes and predict prognostic events in AF patients by analyzing multi-factorial risk factors and using cluster analysis.

### *2.10.3. Hypertensive Patient Classification*

AI helps classify hypertensive patients into clinically meaningful groups based on cardiovascular outcomes and comorbidities, optimizing management strategies and forecasting prognostic trajectories.

## **2.11. Outcome Prediction**

AI-based prognostic models are widely developed in cardiovascular medicine to predict various outcomes.

### *2.11.1. Mortality Prediction*

Deep neural network (DNN) models can predict 1-year all-cause mortality from ECG voltage-time traces, even in patients with ECGs interpreted as 'normal' by physicians.

### *2.11.2. Major Adverse Cardiovascular Events (MACE)*

AI can predict MACE using retinal-vessel caliber data from retinal photographs, with accuracy comparable to or better than expert graders. AI-based analysis of coronary artery calcium and epicardial adipose tissue (EAT) volume from CT scans are also strong predictors of cardiovascular events.

### *2.11.3. Post-Surgical Outcomes*

AI improves the accuracy of risk prediction before and after cardiac surgery, including predicting 30-day hospital readmission rates using machine learning models like random forests

## **2.12. Opportunities for AI in Cardiovascular Medicine**

AI presents significant opportunities to enhance various aspects of cardiovascular care, from prevention to personalized interventions [30][31].

### *2.12.1. Early Detection and Prevention*

AI can facilitate early detection of CVDs, even in asymptomatic patients, allowing for timely interventions and slowing disease progression. This capability is crucial for preventive medicine[32].

### *2.12.2. Precision Medicine*

AI enables personalized treatment plans by integrating multi-dimensional patient data, leading to more tailored and effective interventions.

### *2.12.3. Enhanced Efficiency and Workload Reduction*

AI can automate laborious tasks, reduce alarm fatigue in in-hospital monitoring, and improve resource allocation, thereby increasing healthcare efficiency and reducing the burden on clinicians[33].

### *2.12.4. Remote Monitoring and Wearable Technologies*

AI combined with wearable and implantable devices can provide continuous monitoring of cardiovascular status, identify disease states, and define wellness parameters, facilitating "at-home hospital" monitoring and preventing disease progression.

### *2.12.5. Drug Discovery and Genomics*

AI algorithms can predict common CVDs using personal genomics, identify monogenic causes for targeted drug development, and classify genetic variants as benign or pathogenic, accelerating drug discovery and improving genetic testing.

## **2.13. Challenges for AI in Cardiovascular Medicine**

Despite its potential, the implementation of AI in cardiovascular medicine faces several challenges that need to be addressed for safe and effective integration [34]

### *2.13.1. Data Quality and Availability*

A major challenge is the lack of large, well-labeled, and representative imaging datasets for training AI/ML models. Clinical repositories often contain class imbalances and biases, hindering model generalizability. Annotation of in-hospital monitoring data is labor-intensive and complicated by noise and artifacts, limiting the availability of high-quality datasets [35].

### *2.13.2. Lack of Rigorous Prospective Evaluation*

Many AI/ML-based monitoring systems lack rigorous prospective evaluation, and few studies have tested their effect on clinical outcomes in real-world settings [35]. There is a need to develop robust frameworks to apply AI/ML algorithms across different clinical scenarios.

### *2.13.3. Interpretability and Trust*

The "black box" nature of many AI algorithms makes it difficult for humans to comprehend their intermediate layers and understand how they detect diseases [29]. This lack of explain ability can hinder trust and adoption by clinicians.

### *2.13.4. Generalizability and Transferability*

AI algorithms developed in specific cohorts or centers may not be transferable to other external patient populations or diverse healthcare systems due to differences in data collection, equipment, and clinical workflows.

### *2.13.5. Ethical, Privacy, and Regulatory Concerns*

The application of AI in healthcare raises ethical considerations regarding bias, privacy, accountability, and the risk of dehumanizing healthcare [36][37], [38]. Regulations are needed to ensure that AI/ML algorithms are safe, effective, and efficient.

### *2.13.6. Cost-Effectiveness and Implementation*

The cost-effectiveness of AI technology in auxiliary diagnosis needs further study, as does its impact on clinical practice and resource utilization. Ensuring AI-based tools are cost-feasible and accessible, especially in remote and under-resourced areas, is crucial to avoid exacerbating inequities.

### *2.13.7. Integration with Existing Systems*

Few hospitals have the necessary infrastructure to integrate physiological monitoring with other systems, which can widen the gap between well-resourced and less-resourced hospitals. Interoperability standards between devices and electronic health systems are also needed for effective data sharing.

### 3. Specific Challenges in Precision Medicine and AI Integration

In precision medicine, the integration of big data for developing individualized diagnostics and therapeutic approaches faces additional challenges in data standardization [39] [40]. These include the development of consolidation, characterization, validation, and processing standards for diverse data types, as well as creating ontologies and knowledge relationships for entities such as genes, drugs, diseases, and patient-specific factors [40]. For AI, issues like the curse of dimensionality (where the number of variables greatly exceeds the number of samples), data heterogeneity, and class imbalance (uneven sample sizes in feature groups) further complicate the development of effective models. The lack of standardized, high-quality, large-scale data across institutions remains a significant obstacle for AI development, validation, and reproducibility in medical imaging [41]. Overcoming these challenges is crucial for maximizing research insights and driving innovation in healthcare. Artificial Intelligence in Precision Medicine overview in table 1.

**Table 1** Integration of Artificial Intelligence in Precision Medicine (Oncology and Cardiology)

Domain	AI Application Area	Precision Medicine Function	Example / Outcome
<b>Oncology</b>	Early Detection and Diagnosis	AI analyzes medical imaging (CT, MRI, pathology) to identify tumors at early stages	Earlier cancer detection and improved diagnostic accuracy
	Genomic Profiling and Biomarker Discovery	Machine learning integrates genomic data to find actionable mutations	Enables targeted therapy and personalized treatment plans
	Treatment Optimization	Predicts patient-specific response to chemotherapy or immunotherapy	Reduces side effects and improves treatment efficacy
	Prognosis and Disease Progression	AI models predict tumor growth and survival outcomes	Supports tailored long-term management strategies
<b>Cardiology</b>	Risk Stratification and Prediction	AI analyses ECG, imaging, and EHR data to identify at-risk patients	Early intervention and prevention of major cardiac events
	Diagnosis Support	Deep learning aids in detecting arrhythmias, heart failure, and ischemic disease	Faster and more accurate diagnosis
	Personalized Treatment	AI-guided precision dosing and therapy selection	Optimized treatment with fewer complications
	Remote Monitoring and Decision Support	AI-driven wearables and monitoring systems track heart health continuously	Real-time feedback and proactive care
<b>Cross-domain Integration</b>	Data Integration and Predictive Analytics	AI unifies multi-omics, clinical, and lifestyle data across diseases	Enables holistic, patient-centered healthcare
	Digital Twins and Simulation Models	Virtual models simulate individual patient outcomes	Supports preventive and adaptive treatment planning

#### *Future Directions*

The methodology included identifying future research directions and areas where AI could have a significant impact. This involved looking at advancements needed for integrating AI into clinical workflows, developing more reliable and reproducible imaging and blood biomarkers, and fostering multidisciplinary collaboration among medical professionals, researchers, and industrial partners. The importance of clinical trials to validate AI and machine learning models in predicting and diagnosing cardiovascular outcomes in cancer patients [42],[43]

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## 4. Conclusion

Artificial Intelligence has significantly progressed in advancing precision healthcare in oncology and cardiovascular treatment. While challenges such as data governance and model interpretability persist, ongoing innovation and collaboration promise to bridge these gaps. As AI evolves, it will play a pivotal role in empowering clinicians, personalizing therapies, and improving patient outcomes in both cancer and cardiovascular care.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

According to the corresponding authors, they have no conflicting interests.

### *Author's Contributions*

All authors have equal contribution of the study. All authors read and approved the final version of the manuscript.

### *Declaration*

We will inform participants that we will not divulge any personal information. Participants will receive the signed informed consent form for their records.

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