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Artificial Intelligence Supported Patient Care in Cardiovascular Diseases:A Paradigm Shift from Conventional to Digital

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ABSTRACT
In the transforming era of healthcare, evolving digital innovations have proven to be a powerful tool in cardiovascular medicine and diagnostics. Artificial intelligence is popularly well known as machine intelligence, the computer science branch that simulates the human mind process. Interestingly, cardiology is at the forefront of the AI revolution in the field of medicine. It inculcates the complex computational algorithms that assist in managing the exploding multidimensional data, analyzes the information, imaging, and automates clinical decision making or a range of other tasks. Currently, AI is being employed in various sectors of healthcare, such as diagnosis and treatment recommendations, administrative actions, clinical decision making, problem solving, non-invasive modalities, detection and interpretations, use of wearable devices, and patient engagement and adherence, etc. The rapid pace of artificial intelligence highlights that the future of cardiology will be heavily based on these emerging digital advancements, despite knowing the ethical dilemmas in the implementation of AI in the actual world.
Keywords*: artificial intelligence, cardiovascular diseases, patient care.*

INTRODUCTION

Artificial intelligence (AI) is an intelligent system based on field of computer science that takes the best possible course of action after studying the problem of building agents in a specific situation.[1] Alan Mathison Turing proposed artificial intelligence more than sixty years ago.[2]

Terminology of AI

Artificial intelligence is a non-technical, popular term that refers to various types of machine learning.[3] **Table 1** depicts AI technologies.

Table 1: Various artificial intelligence technologies

Type of learning	Meaning & Strengths
Machine learning	It is defined as an interdisciplinary field that uses statistical techniques to give computer systems the ability to "learn" from a given data set, without being explicitly programmed in a certain manner. It's the most common form of AI, & a broad technique at the midst of various approaches to AI and it has variety of versions. The most common application is precision medicine.
Deep learning	A type of machine learning that uses algorithms in multi layered neural networks for processing large amount of raw data. It is the most complex forms of machine learning that includes deep learning or neural network model. Recognition of potentially cancerous lesions in radiology images is the commonest application of deep learning in healthcare system.
Artificial neural networks (ANN)	A framework for many different machine learning algorithms to work together and process complex data inputs. The working is inspired by the human brain neural structure. It acts like neurons as each neuron is connected likewise to each other. It aids in predicting the disease incidence and decision making.

Natural language processing	It refers to the recognition of speech and evaluation of languages with the use of different technologies, like POS, Parsing, tagging using Hidden Markov Model (HMM). It is used in clinical decision trials, supports or for analysis of the unstructured data in medical field and assists in automated coding as well as helps in maintain the patient's clinical documentation.
Support vector machines	Support vector machines determines the class groups for the given input data. It is used to solve the issue of data classification in the primary basis. These are used in email spam filters when an SVM classifier is trained. It is used to collect and process the medical data. It also helps in making an evidence-based decision.
Heuristics analysis	Heuristics analysis is a technique that uses a trial-and-error method for detection and discovery of the solution, in order to solve a problem. The basic algorithm is to employ such a practical solution which it may not yield the optimal goal but works sufficient to fulfil that goal.
Supervised learning	A type of machine learning that learns patterns from known data sets with known responses.
Unsupervised learning	A type of machine learning that learns patterns from unlabeled data sets.
Convolutional neural networks (CNNs)	Consists of layers of hidden nodes for processing information and is a type of ANN which "learns" by different mechanisms and help in image processing and complex data processing.

Necessity of AI in cardiology

Recent trends in CVD outcomes, costs, and innovation demand a call to action, and there are promising reform directions that could alter these trends. With this call to action, the Value in Healthcare Initiative–Transforming Cardiovascular Care will embark on its work. Artificial intelligence has been progressively identified as a promising technology in cardiovascular medicine. Developing digitalization, such as social networking, obile apps, and wearable devices, provides a considerable amount of constant and real-time medical or healthcare information, shedding light on the potential of implementing artificial intelligence to identify hidden risk predictors.

In addition, AI may assist in discovering precise risk prediction models for CVD patients by uniting CVD risk predictors along with multiomics (e.g., genomics, metabolomics, proteomics, behavior, socioeconomic, and environmental factors), in addition to developing personalized treatment processes for CVD patients.[4]

The burden of CVDs seems inescapable in low- and middle-income countries, and there are various explanations for the rising burden, such as poor infrastructure, lack of resources, quality of healthcare, cost of care, equipment availability, expertise, skills, and the latest research evidence in the field.

It is very importance to highlight that epidemiological data on CVD or risk factors are diverse in different populations or settings, due to cross-cultural differences, food patterns, and environmental or lifestyle variations. More importantly, the evidence for therapeutic regimens is largely derived from high-income countries or Western cultures.[5] Effectiveness of therapies varies from Asian to Western ethnicity, LMIC still follow Western guidelines, which may not provide optimal results in LMIC settings, such as India.[6] These reasons claim the need or importance of studying the epidemiology or therapeutics of artificial intelligence in our culture or setting. Furthermore, the list of reasons provided here enables us to understand the need for artificial intelligence in cardiology and its paradigm instead of conventional.

a) Cardiovascular disease prevalence

The increased incidence of CVD is a contributing factor in artificial intelligence emergence to deal with large data, to diagnose, to make clinical decisions, etc. CVDs are the silent killers and the ruling cause of disease burden and deaths globally.[7], In developing countries, the rise in CVD burden has taken over several decades due to a persistent ongoing period of epidemiological transition.[8] CVD has now become the leading cause of mortality in India as well.[9] However, CVD and its risk factors have peaked within a very short span of time, due to the fast-growing rate at which the Indian economy developed post-independence. The prevalence is inflated in urban areas in comparison to rural areas.[8]

In 2019, approximately 17.9 million people lost their lives from CVDs, representing 32% of deaths worldwide.[10] Ischemic heart disease (IHD) and stroke comprise most of the cardiovascular deaths in our country, India, with ischemic heart disease contributing predominantly.[9]

In accordance with the WHO, India accounts for one-fifth of noncommunicable disease deaths worldwide.[10] The global burden of disease study mentioned the age-standardized CVD death rate, i.e., 272 per 100000 population in India which is much greater than the global average of 235. CVD strikes Indians a decade earlier than the Western population.[11] It focuses on the fact that AI is needed to address the rising number of CVDs globally.

Studies have highlighted the increasing CHD prevalence in India over the past sixty years, from <1% to 4%-6% in rural populations and 1% to 9%-10% in urban populations.[12]

The reports encoded by LASI state that cardiovascular disease was seen higher for those living in urban areas in J&K (51%), Telangana (46%), West Bengal (44%) and lower in Arunachal Pradesh (12%), Nagaland (22%) and Mizoram
(28%).[13]

b) **Hospitalization and mortality**

Globally, 1 in every 3 deaths is a consequence of CVD, although the majority of premature heart disease and stroke cases are preventable. Approximately 80% of CVD deaths occur in low-to middle-income countries such as India.[10] A study by global burden of disease and the World Health Organization (WHO) have highlighted increasing trends in disability-adjusted life years (DALYs) and years of life lost (YLLs) from CHD in India.[14]

The medical certification of cause of death (MCCD) reports underlined the points of an expansion in the CVD death proportion. It surged from 20.4% in 1990- to 27.1% in 2004.[13]

The years of life lost attributable to CVD in India increased by 59% from 1990 to 2010 (23.2 million to 37 million).

Between 1990 and 2016, CVD death rates are estimated to have risen from 155.7 to 209.1 per 100,000 in India.[9] **c) Quality of life**

Cardiovascular disease imposes substantial burden on quality of life of patients.[15] Patients with myocardial infarction have a high risk of depression and show a higher probability of having a poor quality of life.[16] **d) Cardiovascular disease costs to society**

In 2010, the CVD cost was US$ 863 billion,- which is estimated to rise by 22% to US$ 1,044 billion by 2030.[17] The WHO estimated,- that India would lose $237 billion from the loss of productivity and spending on health care over a 10-year period (2005–2015).[10]

The Government of India announced a hike in public health expenditure to 2.5% of the GDP in 2017, acknowledging the rising burden of CVDs in India.[9]

e) Current state of cardiovascular disease care

There are barriers to accessing and using more sophisticated and specialized cardiovascular therapies if risk factors cannot be successfully controlled with the suggested first-line interventions and treatments or if CVD advances despite the use of recommended interventions. Clinical practitioners' and patients' experiences show that, even in instances where access to sophisticated therapies is medically necessary, there are substantial practical obstacles.[1] Patients who pass away from cardiovascular reasons are less likely to die at home and receive excellent hospice care than those who pass away from other severe diseases, have higher odds of experiencing high end-of- life expenses, and have more symptoms.[2]

f) The heart failure clinics or HF registry

Heart failure, being one of the greatest drivers of morbidity and mortality in India, necessitates the emergence of heart failure clinics or heart failure registries.[18] Management and administration demand a cautious and thoughtful approach in developing such clinics. Currently, in India, there are limited or very few advanced practice heart failure specialized clinics or registries.[19] Additionally, the limited specialization of nurses trained in heart failure management or the lack of lab assistants or technicians unfolds the training needs required in the digitalized era. The basic need is to upgrade the interventions or clinics with the help of clinicians/physicians or cardiac specialists in our country.

g) The lack we have in the framework-WHO building blocks

The WHO framework for the health system has characteristically six building blocks of a well-functioning health care system that is necessary to improve health outcomes.[20]

i. Service delivery ii. Health workforce iii. Health information system iv. Access to essential medicines

v. Health financing to protect patients from financial catastrophe vi. Importance of leadership and governance.

India, as a developing middle-income country, lacks almost one or all building blocks; therefore, India needs to work even harder to build up strategies for quality improvement in the country to combat the rising cardiovascular disease burden.

APPLICATION OF AI IN CARDIOLOGY

The modern generation or the population in developed countries tends to look for health-related information through electronic sources and web-based risk calculators.[21]

AI-CDSS, a web-based application is a technology for use by physicians in real clinical practice and was developed by D.J. choi et al. The knowledge was integrated into various formats of the HF diagnosis system and was built with consolidation of the standard data model and the standard terminology.[22]

In medicine, AI plays a vital role; it collects, records, and stores data electronically to facilitate faster decision making, diagnosis and treatment. AI accurately analyzes different tests such as X-ray, USG, magnetic resonance imaging, and computed tomography scans, and quickly shares patient information in emergency situations.[23] It manages all medication systems and medication alerts and assists in patient monitoring and proper diagnosis and treatment.

AI systems have potential ground-breaking applications in drug discovery, personalized medicine therapy, and accurate and precision medicine in population genetics.[24]

More recently, applications of AI have become relevant in five main clinical areas of cardiology.

i. **AI in heart failure:** AI augments diagnosis and clinical decision making through automated cardiac volume and function measurements. Personalized risk stratification and predicting mortality, medication adherence and future HF hospitalizations.[7]

The AI Clinical decision support system shows enough potential to help and guide physicians in heart failure diagnosis and trials suggest a high diagnostic accuracy for heart failure diagnosis.[22]

AI-CDSS remarkably helps in accurately diagnosing HF and can be useful in LMICs as a screening tool. Apart from identifying at-risk populations, AI-enhanced modalities can also play an important role in preventing hospitalization or can predict readmission rates for HF patients. It can additionally help in selecting a particular therapy of treatment with specifically low LVEF patients or patients with prolonged QRS duration requiring

CRT. Furthermore, it may assist in identifying responders and non-responders to CRT.[25] ii. **AI in hypertension**: The evolving clinical implementation of AI provides the advantage of acquiring expertise in the diagnosis or prediction of hypertension. AI or ML accurately predicts real-world evidence from electronic health records. AI can predict systolic blood pressure on the basis of retinal fundal images, risk of developing essential hypertension in the next year or 5 years cause mortality or survival prediction, predict clinical outcomes predict effective antihypertensive therapies, discover hypertension-related genes, etc.[26] iii. **AI in ECG**: ECG has been one of the most ubiquitous tools used in clinical settings for decades. Neural networks formed with the use of digital ECGs linked to a large number of clinical data sets might perform human-like accurate interpretations of ECGs. AI-enhanced neural networks have been developed to detect hypertrophic cardiomyopathy, silent atrial fibrillation, aortic valve stenosis, asymptomatic left ventricular dysfunction amyloid heart disease, sex, age, and race of individuals on the basis of ECG alone. The neural networks might be applicable to obtain data from the single lead, multi-lead mobile or wearable ECG technology or with the standardized 12 lead ECG. Ultimately, AI enhanced ECG has the potential to detect or predict CVDs in at risk populations.[27] iv. **AI in Echo**: AI application in echocardiography has valid potential to optimize the diagnostic ability of echo. It assists in recognizing the standard section, automatic classification of cardiac views, functional assessment of the left ventricle, diagnosis of cardiac diseases, intracardiac masses, cardiac cavity automatic segmentation, etc. It provides practical auxiliary assistance to the cardiologists, and gradually the transformation of formulating disease diagnosis with AI-assisted technologies is on its way forward.[28]

v. **AI in CT and MRI in CV diagnosis**: Recent AI algorithms and technology have revolutionized the development and application of cardiac imaging. AI has accelerated quantitative automated imaging technology to diagnose disease conditions or to personalize treatment strategies. It helps in image deblurring and image denoising. AI is widely used in coronary CT angiography, fractional flow reserve CT, left ventricular myocardium analysis, coronary artery calcium scoring, CAD prognosis, cardiac function assessment, plaque analysis, and cardiomyopathy prognosis.[29] vi. **Valvular heart disease**: improving clinical diagnosis by applying AI algorithms to phonocardiograms, ECGs and non-invasive

imaging modalities. Facilitates the appropriateness and prognostication of interventions. vii. **Electrophysiology:** Enhances the diagnosis of arrhythmias, electrolyte derangements and structural cardiac disease. Personalized prediction of future cardiac events including the development of arrhythmias. viii. **Coronary artery disease**: prediction and risk stratification of patients presenting with ACS. Prognostication of mortality and major adverse cardiovascular events. ix. **Smart wearables**: Smart wearables generate a plenitude of data by means of various detectors and algorithms. An understanding of the basic knowledge of application, engineering principles and limitations can be of great help to clinicians and scientists.[30]

TOOL AND STRATEGIES OF AI IN CARDIOLOGY

A literature review found that artificial intelligence technologies for various cardiovascular diseases are in under development, and they are gradually discovering models that are suitable for wear and mobile devices. Acute coronary syndrome patients benefit from artificial intelligence-supported early revascularization strategies. However, selection method for patients requiring immediate revascularization among those visiting the emergency room with chest pain symptoms is not yet fully convincing. ECG is an economical and fast procedure, that is considered to be easy, but it might contain crucial recordings that are not recognized even by well-trained physicians.[31]

AI precisely influences nursing workflow. Recently, the COVID pandemic led to the development of nursing robotics that can particularly takeover nursing tasks and accompany patients by performing nursing roles.[32] One such example lies in Japan, where AI-powered robots are in use to help older adults perform daily living activities in chronic care facilities or hospital settings.[33]

Additionally, virtual nurses, also well known as virtual healthcare assistant apps, are also of great importance. These virtual nurses perform functions to provide information, interpret lab values, ask questions, etc. AI health technologies describe various models to predict the readmission rate in heart failure patients utilizing machine learning models.[33] Additionally, wearable camera devices were used to collect in detail information about the lived experiences of patients with cardiovascular disease. Other AI for cardiovascular nursing have great potential for this field, as many diagnostics and treatments are based on digitalization and specific patient data.[34]

AI AND ROADMAP TOWARDS CARDIOLOGY

The era of exploring AI has been ongoing in recent decades. However, it is in use due to recent advancements that it has brought to the health sector. AI contributes to significantly improving the efficiency of healthcare services, significantly improving time management, reducing costs, improving decision making, helping in technological learning and many more.

Machine learning-based data-driven techniques might enhance the risk prediction performance by agnostically recognizing new risk predictors and understanding the multiplex interactions between them. **Figure 1** depicts the traditional and artificial intelligence-supported patient care concept of paradigm shift from conventional to digital mode in cardiovascular disease treatment.

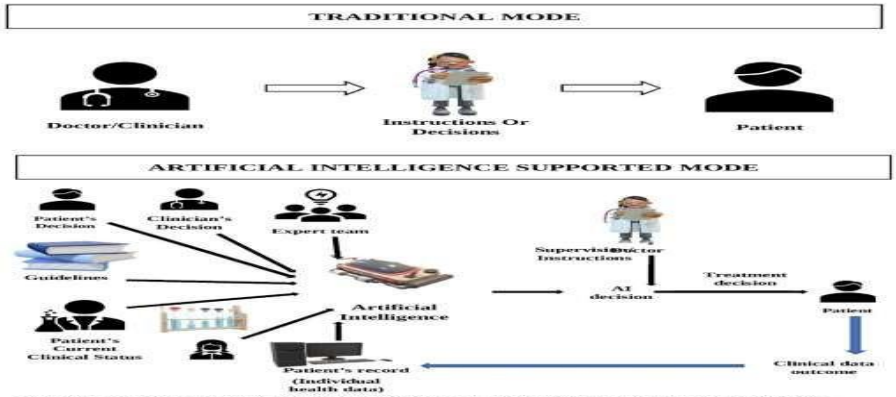

Figure 1: Traditional and Artificial intelligence supported patient care concept of paradigm shift from conventional to digital mode in cardiovascular disease treatment, AI: Artificial Intelligence.

Various groundbreaking publications concern artificial intelligence-based medical technologies/software thus far. A few recent studies are listed in **Table 2.**

Table 2: List of different groundbreaking AI-based medical innovations

S.No	Innovation	Use
1.	Steth IO	To detect and amplify sounds from heart & lungs
2.	Arterys Cardio DL	To analyze cardiovascular images from MR scans
3.	KardiaAI	To assess ambulatory ECG rhythm
4.	EchoMD automated ejection fraction software	To provide automated estimate of LVEF based on acquired transthoracic cardiac USG images
5.	Acumen hypotension prediction index (HPI)	To support detection of future hypotensive events
6.	EMurmur ID	To identify and detect heart murmurs
7.	AI-Rad Companion	Image processing software to analyze CT images
8.	FFRangio	To analyze angiography
9.	AI ECG Tracker	To assess arrhythmias using ECG data
10.	Bodyguardian remote monitoring system	To arrhythmia detector and alarm
11.	Analytic for hemodynamic instability (AHI)	Adjunctive hemodynamic indicator with decision point
12.	Gili Pro Biosensor	For optical camera-based measurement of pulse, heart rate, breathing rate
13.	LINQ II insertable cardiac monitor, Zelda AI ECG classification system	Detects arrythmia and alarm
14.	Atrial fibrillation history feature	Detection of atrial fibrillation

BENEFITS OF AI IN CARDIOLOGY

- It helps in participative medicine, as both the patients and healthcare professionals collaborate to work to improve the patient's condition.
- Furthermore, artificial intelligence supports changes in the case process using eHealth, and provides a better opportunity for personalized therapy.
- It adds value to the healthcare system and helps in early detection and prevention.
- It is a step toward a cost-effective, timely approach.
- AI assists in daily clinical decision making and improves efficiency by providing a better cardiac healthcare solution.
- AI provides proper cardiovascular image interpretation, helps with patient records and is useful for computer-aided diagnosis.
- It assists in patient care even at a distant location, focuses on raising awareness clinically and reduces cost burden.
- It improves the teaching learning process, research and development.
- It enacts a sustainable economic model for integrated cardiovascular disease care.
- Values social and economic impact over the population.

CHALLENGES AND LIMITATIONS OF AI

- It requires close collaboration between modern technology and traditional medicine, as well as knowledge and intellect of how the technology will be welcomed and embraced by different stakeholders, from providers to the users or clinicians to regulatory bodies.
- Data privacy or security and governance is an important concern, as breach or illegal sharing of data could hamper services; therefore, cybersecurity tools should be developed and encouraged, such as blockchain, which could be taken into consideration.
- Inaccurate data are more harmful than no data, so defined regulatory policies
- Legal, societal, and ethical issues can be associated with artificial intelligence, as our population is not so comfy with this approach.
- To curb the cardiovascular epidemic currently sweeping our nation, key attention has been given to sensitizing the government to formulate an approach that could fill the gap between the establishment of a robust surveillance system, improvement in the efficiency of care and health system preparedness. Additionally, to preserve traditional lifestyle patterns, it is essential to step side by side.

- Data management and storage are necessary; therefore, the government needs to develop policies that incentivize semantic interoperability to use technologies.

FUTURE PROSPECT OF AI

In our fast-paced era, time is limited and extremely precious. Healthcare faces crises due to a lack of experienced staff and departments and a high rate of demanding the best possible treatments at the lowest cost. AI is gradually taking over human beings and focuses on unifying their knowledge along with artificial intelligence-derived suggestions for reliable and precise decision making in each phase of the decision-making process.[35] Randomized clinical trials are the cornerstone demonstrating the clinical utility of various new-interventions in advanced cardiology.[7]

Although artificial intelligence is currently still in the budding stages, accumulating evidence suggests that artificial intelligenceguided research in cardiology permits researchers to investigate novel certainties contributing to the pathophysiology of various cardiovascular diseases by applying machine learning and deep learning to big data with multimodal inputs, such as demographic data, vitals recording, cardiovascular risk & imaging, multiomics, behavioral, socioeconomic and environmental factors. The potential of artificial intelligence to exclusively recognize factors linked with cardiovascular disease evolution can be used for earmarking individuals at greater risk of cardiovascular illnesses and may profit from lifestyle modification for cardiovascular disease primordial prevention.

It is not enough to develop AI technologies; rather, a more important aspect is to adopt or integrate these services into routine clinical practice to improve the practices in a timely manner. The approval of AI and its standardization seems to be a major challenge; as a result, it is expected that there will be limited use of artificial intelligence technologies in clinical practice within the next few years. It seems quite clear that AI will not replace human clinicians on a huge scale but instead will surely assist and augment their efforts in patient care.

CONCLUSION

The universal and profound footprints of artificial intelligence (AI) in present modern society are indubitable. While emerging technology is already in use and acts as a convincing tool in various professions, it has recently made the move to transform the practice of medicine. The review aimed to provide an overview of AI and machine learning algorithms to cardiovascular medicine healthcare providers that have passed the initial tests and made it into contemporary clinical practice.

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Author contributions

All the authors have contributed equally to the manuscript. The manuscript has been read and approved by all the authors.

Conceptualization, N.K.; methodology, N.K. and A.K.B.; software, validation, formal analysis, S.K.S.; investigation, resources, data curation, S.D.; writing-original draft preparation, A.K.B.; writing-review and editing, N.K., S.K.S., and S.D.; visualization, supervision, project administration, funding acquisition, N.K., S.K.S., S.D., and A.K.B.

Conflicts of interest

There are no conflicts of interest to declare**.**

Data accessibility

Data sharing not applicable to this article.

Ethical issues

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