REVIEW ARTICLE

Artificial Intelligence in Cardiovascular Diseases: Bytes for Beating Hearts

S. Lakshmi Manideep Royal[1], Prasanthi Samathoti[2], C. SaiSukeerthan Reddy[3], S. Sudhesh Sreepathi[3], B. Akhil Naik[3], M. Sai Deepa[3], N. Sree Lekha[1], V. Sarovar Reddy[4]

[1]Department of Pharmacy Practice, Annamacharya College of Pharmacy, Rajampet, Andhra Pradesh, India, [2]Department of Pharmaceutics, Mohan Babu University (Erstwhile SreeVidyanikethan College of Pharmacy), Tirupati, Andhra Pradesh, India, [3]Department of ???, Annamacharya College of Pharmacy, Rajampet, Andhra Pradesh, India, [4]Department of Pharmaceutics, Annamacharya College of Pharmacy, Rajampet, Andhra Pradesh, India

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Abstract

Cardiovascular disease remains the leading culprit of death in the entire world. It poses one of the grave and rising burdens on healthcare systems. In this case, artificial intelligence (AI), especially its parts, machine learning and deep learning, has become a valuable companion of clinicians who are no longer seeing it as a subject of scientific curiosity. This review paper will look at the influence of AI in the practice of modern cardiology. We discuss how AI is transforming cardiovascular imaging by simplifying complex diagnosis and revealing subtle problems in echocardiography and advanced syjtrtcans. We consider the spectacular recovery of the electrocardiogram. This is possible with the assistance of AI to foresee future arrhythmia and unseen heart diseases on just a normal, uninstructed tracing. We also discuss the trend toward much more personalized risk assessment, going far beyond the scoring systems developed in the past. Nevertheless, there are pitfalls on the way to the algorithm and clinics. In this review, the reviewer examines the four main challenges of data bias, the black box issue of explanation, regulatory complications, and the introduction into clinical practice. When examining further what these opportunities and challenges may mean in India, we propose that AI is not a replacement for clinicians. Rather, it is a device to provide augmented intelligence with a future of more predictive, precise, and preventive cardiovascular healthcare.

Key words: Artificial intelligence, cardiology, cardiovascular disease, deep learning, electrocardiogram, echocardiography, health equity, machine learning, risk prediction

INTRODUCTION: CONFRONTING THE UNYIELDING CARDIOVASCULAR EPIDEMIC

Cardiovascular disease (CVD) is a modern-day epidemic. It poses a threat which results in close to a third of the deaths in the world. This is a startling figure that represents very many more than 18 million lives a year.[1] Things are looking bleak in India as well. CVD has risen up to be the leading cause of death. It commonly strikes individuals in the middle of their lives, a decade before the people in the Western world.[2] Against this continuing tidal wave, the medical world has fought back over the centuries with an increasingly sophisticated armory of diagnostic devices, first the simple stethoscope and more recently the wonders of cardiac imaging. However, the clinical complication of the disease, its generally a minor manifestation and some of the clinical evidence is so intricate that it can easily go beyond human thinking and intuition.

Into this, potpourri of clinical demand is artificial intelligence (AI). In contrast to the science-fiction worlds, AI in medicine is a valid and practical bundle of computational aids. Machine learning and deep learning are the subfields of it operating as

Address for correspondence:
S. Lakshmi Manideep Royal,
Department of Pharmacy Practice, Annamacharya College of Pharmacy, Rajampet - 516 126,
Andhra Pradesh, India. Phone: +91-7032386194.
E-mail: manideeproyal1999@gmail.com

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professional pattern-recognition systems. They are developed to handle vast and complicated information, medical maps such as pixels of an echocardiogram, electrical data of an electrocardiogram (ECG), and text in millions of electronic health record (EHRs). Such systems are able to unearth latent and detailed patterns that even human clinicians will be unable to discern.[3]

The buzz of AI in cardiology is not to substitute the judgment or an understanding of a cardiologist; it is to supplement it. It is pursuing the concept of augmented intelligence, in which human specialists rely on an aid that can see further, faster, and more accurately predict. This paper is going to discuss the most significant usages of AI in contemporary cardiology, as well as the way it is transforming our major diagnostic tools. Both what is required to achieve widespread implementation and fair implementation will also be discussed as a critical challenge in itself. This is fundamentally the account of how the world of big data and algorithms are beginning to make a difference on the millions of at-risk beating hearts.

REINVENTING IMAGING OF CVDS: A VIEW OF THE UNSEEN

Contemporary heart diagnostics cannot be done without cardiovascular imaging. It assists us in viewing the anatomy and physiology of the heart. Nonetheless, the interpretation of these images may require much time. It takes years of training and it can usually be influenced by varying interpretation between experts. With the power of intelligence augmentation, this can change as analysis can be automated and new diagnostic insights discovered.

In the AI era, the echocardiogram shows

One the most common cardiology tests is the echocardiogram; it is a non-invasive heart ultrasound. An important step in the process of interpreting it is the manual tracing of the endocardial border at different stages of the cardiac cycle. This is used to determine the left ventricular ejection fraction (LVEF) which is considered as a good indication of pumping strength of the heart. This process is strenuous, and it is sometimes not easy to give consistent results. The entire process can now be automated via deep learning models now with superhuman speed with impressive accuracy. These AI models can thus learn by training hundreds of thousands of existing echocardiograms to recognize the heart chambers and automatically determine LVEF and other essential parameters such as myocardial strain and more within a few seconds using raw video clips. Not only does this save much time on the part of sonographers and cardiologists but it also creates standardization in the measurements, eliminating the variability that could pose problems in monitoring a patient over time. The effects are greater than mere quantification. New algorithms are in development to automatically screen echocardiograms directly in specific diseases. As an example, conditions such as hypertrophic cardiomyopathy, cardiac amyloidosis, and severe valvular heart disease are reliable to be detected using models to identify suspicious studies that are then reviewed by a human expert.[5] This could be an effective means to screen diseases that would have otherwise not been identified on a basic investigation.

Improving the cardiac computed tomography (CT) and magnetic resonance imaging (MRI)

In more sophisticated cross-sectional imaging technologies such as cardiac CT and cardiac MRI, AI can have a similar efficiency and accuracy-enhancing impact. Segmentation of images is a critical step in imagery data processing of such multidimensional information where the structural pattern of the heart, the myocardium, and the large vessels are outlined. This time consuming task can be efficiently completed by AI-based segmentation software in minutes rather than hours, as a human expert would need to do.[6]

More than that, segmentation is contributing to the progress of clinical applications of AI. In cardiac computed tomography angiography, machine learning algorithms can automatically quantitate the burden of coronary artery plaque, which is the salient feature of atherosclerosis, and perhaps even characterize such plaque (e.g., calified vs. non-calcified), essential prognostic information.[7] In cardiac MRI, AI can assist in measuring the degree of myocardial scarring following a heart attack, or indicating subclinical diffuse fibrosis, providing information about a patient at risk of arrhythmias and heart failure.

REVEALING THE SECRETS OF THE ECG: A RENAISSANCE OF A HUNDRED-YEAR-OLD DEVICE

The 12-lead ECG is an important medical device. It dates back to more than 100 years. It is economical, has non-invasive properties, and is available in virtually all settings, including upscale cardiac intensive care as well as a small-town primary care setting. We had already believed, many years, that we were with its familiar waveforms familiar with the entire diagnostic potential of. I has altered this belief in the case of I, it demonstrates the fact that even the simplest ECG contains masses of biological information that can be much more profound than we imagined. AQ3 AQ3

The most life-changing advancement has been the innovating of the AI-ECG. It involves deep learning to interpret raw 12-lead ECG data. The AI acquires patterns that cannot be perceived by human beings. Scientist at the Mayo Clinic discovered a revolutionary thing. They demonstrated that an AI model can analyze a normal ECG with normal sinus rhythm and make correct decisions identifying current or future atrial fibrillation (AFib) patients at risk. Fib is the most prevalent cardiac arrhythmia and the leading cause of the stroke.

Nevertheless, it may be missed or incidentally seen on a regular ECG. The AI managed to pick up some minor structural and electrical alterations in the atria that was indicative of the arrhythmia. The most radical innovation has become the creation of the AI-ECG. This approach adopts the deep neural networks to process the raw 12-lead ECG
AQ3 data. This allows the AI to discover trends that humans are not aware of. The Mayo Clinic made an important discovery. They have shown that a model, created using AI, can review a conventional ECG with normal sinus rhythm and reliably distinguish patients with a previous history of or high
AQ3 likelihood of future AFib.[8] The most prevalent heart rhythm disorder and the brain stroke is caused by Fib. It is however intermittent and can easily be missed by normal ECG. The AI identified the slight abnormalities in the structure and electrical activity of atria that hinted on the possibility of arrhythmia.

It was a breakthrough, because it demonstrated that the ECG had much more information than it would tell you about the current rhythm of the heart, but also past history and predictive wisdom of the heart as well. This idea and notion have been rapidly developed.

Diagnosing occult heart failure An AI-ECG can now distinguish between patients with an occult heart failure like low ejection fraction. This condition is an antecedent to congestive heart failure and the AI accomplishes this with great precision.[9] This may create convenient and broad-based screening of a silent yet an alarming condition.

Diagnosis of structural disease

AI models are able to diagnose other poorly recognized structural diseases including hypertrophic cardiomyopathy[10] and cardiac amyloidosis based solely on the ECG. Such conditions normally require extensive imaging to be diagnosed.

Further than the heart AI can use the data contained within ECG to determine the biological age and sex of a patient, electrolytic imbalances like hyperkalemia, and non-cardiac conditions like anemia.[11]

Such a renaissance of the ECG due to AI has gigantic implications. It has the ability to transform this low-income, standard examination into an effective method of screening a population. It can also be used to identify people who are at risk of developing several conditions earlier than they exhibit symptoms. Besides, AI is transforming the method of arrhythmia detection in regular devices. The use of algorithm in smartwatches and other wearables now allows detecting AFib in real-time and motivating people to receive medical attention as promptly as possible.[12]

INDIVIDUALIZATION OF RISK FORECASTING AND CONTROL

Prediction of risk of CVD relied on long-established statistical tools such as the Framingham Risk Score or ASCVD Risk Estimator, even during the last few decades. These scores have been helpful yet only limited conventional clinical factors including age, cholesterol, and blood pressure have been considered. AI offers an opportunity to craft more detailed, flexible and personalized hazard projections.

A far greater variety of data sources can be used with machine learning models. They are able to utilize thousands of variables in a patient total EHR, genetic data, proteomic, imagery, and even lifestyle data using wearsome devices. This system provides a comprehensive approach in out-lining the risk status of an individual.[13] These models have always been shown to be more accurate than conventional risk scores to predict specific events such as heart attack, stroke, and heart failure.[14] Such higher precision would enable clinicians to extend beyond guidelines on general populations. It can assist them in more precisely targeting the best preventive measures against CVD (including statins or other new lipid-lowering drugs) to those individuals who will get the greatest benefit. The method will also prevent excessive treatment to the individuals with a lower risk. AI is also penetrating into the therapeutical area. In pharmacology, AI is used to accelerate drug discovery to identify new molecular targets of CVDs. Clinical research can make use of machine learning to better design the clinical trial by identifying which patient groups will best respond to a particular intervention. This had the potential to faster, less costly, and more successful trials.[15]

ON THE WAY TO CLINICAL REALITY

It is true that the rate of innovation has been astounding but, at the same time, the road that extends between a promising algorithm in a research article and a reliable resource on the bedside of a ward has a lot of obstacles. To implement widely, equitably, and with safety, there are several significant challenges that have to be tackled.

The problem of explainability of deep literacy

A major proportion of the most notable deep literacy models are black boxes. They can make highly successful prognostications, but they cannot fluently expound as to why they made those judgments. This loss of translucency is a significant hedge to clinical abandonment. To be able to routinely follow the decision of an AI, especially when it contravenes common sense, a clinician must have faith in the reasoning process it follows. The discipline of "resolvable AI" (XAI) is endeavoring to generate models that can provide insight into their reasoning. However, it is a considerable specialized challenge.[16]

Data bias and health equity

It is one of the ethical problems on the largest scale. The algorithm is just as great, fair, and amazing as the can data available to learn it. A model to predict the likelihood of a heart attack constructed primarily using the data on the health of wealthy, white, male populations in North America may not work well. Worst still, it may cause an exacerbation of the already existing health disparities when applied to women, other ethnicities or individuals in various geographical parts of the world.[17] An algorithm does not behave in an inherently objective way but rather reflects the biases seen in the data with which it is provided. Ensuring diversity and sort of generalizability in training datasets is a key consideration in health equity.

Regulatory and ethical challenges

The regulatory requirements on medical devices typically do not have adaptive and learning algorithms in mind. What can organizations such as the U.S. Food and Drug Administration or the central drugs standard control organization do to approve software that can continuously evolve as it processes new information? Oftentimes, difficult issues of responsibility are raised. In case an AI tool provides a wrong diagnosis, who should be blamed the developer who created the tool, the hospital where the tool was in use or the clinician who made the decision based on the AI tool suggestion? These legal and ethical rules have not yet been formulated completely.[18]

Integration and workflow

An algorithm that is theoretically perfect is of no clinical use should it not integrate easily into the complex and often chaotic real-life clinical workflow. The EHRs already provide clinicians with overwhelming alerts and data. A new AI tool should not move the needle to this alert fatigue but rather provide clear, concise unambiguous actions. It has to be fast and easy to use and it can only enhance, rather than complicate the process of care.

THE INDIAN CONTEXT: HEARTS OF A BILLION BYTES

The possible implications of AI in cardiology are of particular significance to consider in the context of India. In a country of 1.4 billion people with a high and rising burden of CVD, AI is a great opportunity as well as a serious challenge.

The opportunity

In the healthcare where specialists are in high demand and there exists a significant rural-urban transition, AI presents a good opportunity that is likely to be an equalizer. A machine-learning algorithm in a low-cost, portable system would support delivery of an expert-level heart-screening service in a primary health center in a remote village in Andhra Pradesh or in a wellness clinic in Hyderabad. It would be able to reveal a farmer with heart failure or an endangered teacher with AFib, and such individuals could be referred and treated early.[19] A unified and interoperable digital health system is the target of the government through the ambitious Ayushman Bharat Digital Mission. Such a mission would supply the data base necessary to support and justify these AI tools throughout the country.[20]

The ground reality

The ground condition is tough. Health data in India have been inconsistent, dispersed, and generally poor in quality. Due to the immense genetic, social, and lifestyle differences among the Indian population, models developed in the West are likely to be inherently biased and inaccurate when applied here. The greatest challenge is to create large, diverse, high-quality, and representative Indian data sets on which to train and validate AI models.[21] Unless done, AI has the potential of increasing inequality. Furthermore, the real-life barriers such as the cost, digital infrastructure, and training of healthcare staff in rural locations should be considered to have any true impact of these technologies.

CONCLUSION AQ4

The cardiologist of the future with augmented capabilities AI has now become an influential and local sound in cardiology, unlike way back in the past where it was a scanty mumble and a long distance away. It is radically changing how we view the ECG, interpret pictures, and can predict illness. There is substantial evidence that these tools have the potential to make diagnoses more accurate, improve the efficiency of work processes, and even give a glimpse into the realm of truly individualized medicine of the future.

AI in medicine is not a man verses machine thing. It is not meant to replace the experience, intuition, and empathy of the human clinician, which is invaluable. Instead, it is to create the augmented cardiologist, the expert with tools that will improve their perceptions, understandings, and accuracies. The cooperation is the future of cardiovascular care. To advance, we must place both extreme emphasis on stringent scientific validity, extreme adherence to ethical standards and health equity, and extreme caution in implementing such powerful tools within the clinical workflow. The obstacles cannot be ignored, but the possibility to foster the care of

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millions of patients using this information is one of the greatest opportunities of the 21st-century medicine.

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REFERENCES

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1. World Health Organization. Cardiovascular Diseases (CVDs); 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds
2. Prabhakaran D, Jeemon P, Roy A. Cardiovascular diseases in India: Current epidemiology and future directions. Circulation 2016;133:1605-20.
3. Johnson KW, Torres Soto J, Glicksberg BS, Dudley JT, Shameer K, Mitto R, *et al*. Artificial intelligence in cardiology. J Am Coll Cardiol 2018;71:2668-79.
4. Ouyang D, He B, Ghorbani A, Yuan N, Ebinger J, Langlotz CP, *et al*. Video-based AI for beat-to-beat assessment of cardiac function. Nature 2020;580:252-6.
5. Deo RC. Machine learning in medicine. Circulation 2021;143:1437-9.
6. Chen C, Qin C, Qiu H, Tarroni G, Duan J, Bai W, *et al*. Deep learning for cardiac image segmentation: A review. Front Cardiovasc Med 2020;7:25.
7. Van Rosendael AR, Maliakal G, Kolli KK, Beecy A, Al'Aref SJ, Dwivedi A, *et al*. Maximization of the usage of coronary CTA derived plaque information using a machine learning based algorithm to improve risk stratification; insights from the CONFIRM registry. J Cardiovasc Comput Tomogr 2018;12:204-9.
8. Attia ZI, Kapa S, Lopez-Jimenez F, McKie PM, Ladewig DJ, Satam G, *et al*. Screening for atrial fibrillation using an artificial intelligence-enabled electrocardiogram. Lancet 2019;394:861-7.
9. Attia ZI, Noseworthy PA, Lopez-Jimenez F, Asirvatham SJ, Kapa S, Friedman PA, *et al*. An artificial intelligence-enabled ECG algorithm for the identification of patients with atrial fibrillation during sinus rhythm: A retrospective analysis of outcome prediction. Lancet 2019;394:861-7.
10. Ko WY, Siontis KC, Attia ZI, Carter RE, Kapa S, Ommen SR, *et al*. Detection of hypertrophic cardiomyopathy using a 12-lead electrocardiogram-based deep learning model. JACC Cardiovasc Imag 2021;14:1937-48.
11. Kwon JM, Kim KH, Jeon KH, Lee Y, Park J. Artificial intelligence algorithm for predicting mortality of patients with acute coronary syndrome using electrocardiography. Sci Rep 2020;10:12844.
12. Perez MV, Mahaffey KW, Hedlin H, Rumsfeld JS, Garcia A, Ferris T, *et al*. Large-scale assessment of a smartwatch to identify atrial fibrillation. N Engl J Med 2019;381:1909-17.
13. Weng SF, Reps J, Kai J, Garibaldi JM, Qureshi N. Can machine-learning improve cardiovascular risk prediction using routine clinical data? PLoS One 2017;12:e0174944.
14. Al'Aref SJ, Anchouche K, Singh G, Slomka PJ, Kolli KK, Kumar A, *et al*. Clinical applications of machine learning in cardiovascular disease and its relevance to cardiac imaging. Eur Heart J 2019;40:1975-86.
15. Farmaki C, Chondrogiannis D. Artificial intelligence in drug discovery: A comprehensive review. Molecules 2021;26:4504.
16. Rudin C. Stop explaining black box machine learning models for high stakes decisions and use interpretable models instead. Nat Mach Intell 2019;1:206-15.
17. Obermeyer Z, Powers B, Vogeli C, Mullainathan S. Dissecting racial bias in an algorithm used to manage the health of populations. Science 2019;366:447-53.
18. Topol EJ. High-performance medicine: The convergence of human and artificial intelligence. Nat Med 2019;25:44-56.
19. Bhavnani SP. The role of artificial intelligence in strengthening global health systems. Lancet Digit Health 2020;2:e506-7.
20. National Health Authority, Government of India. Ayushman Bharat Digital Mission; 2022. Available from: https://abdm.gov.in AQ6
21. Rajkomar A, Dean J, Kohane I. Machine learning in medicine. N Engl J Med 2019;380:1347-58.

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