Artificial intelligence in pediatric cardiology: Where do we stand in 2024?

Artificial intelligence (AI) refers to the discipline of computer science that enables machines to generate algorithms and simulate human intelligence, that is, demonstrate the ability to learn, reason, analyze, and make decisions.[1,2] In 2019, Dr. Anthony Chang wrote an editorial in the *Annals of Pediatric Cardiology* (APC) titled, “Artificial intelligence in pediatric cardiology and cardiac surgery: Irrational hype or paradigm shift?” highlighting the available technologies related to AI and pediatric cardiology. He envisioned an essential role of AI in improved diagnosis and targeted precision therapies in conditions such as heart failure, pulmonary hypertension, and arrhythmias. He further discussed studies demonstrating how AI can improve pediatric cardiac decision-making and intensive care unit (ICU) care.[3] Now, 5 years later, we are in an era of democratized access to basic AI, where Chat Generative Pre-trained Transformer (ChatGPT) and Microsoft Copilot are freely available tools that are being extensively used by millions of people in various fields to automate simple tasks ranging from making PowerPoint presentations to travel itineraries and instantly generating solutions to mundane but time-consuming tasks. However, a recent study demonstrated that AI chatbots in their present form are still not reliable enough to help in decision-making in medical fields.[4] In this experiment, the authors quizzed ChatGPT 4.0 with 88 multiple-choice questions from a pediatric cardiology board review textbook, and the chatbot scored only 66%.[4] This compared poorly with previous studies testing ChatGPT 4.0 on the United States Medical Licensing Examination (USMLE) questions (where the model scored in the 90th centile) and suggested that nuanced understanding of complex subspecialty fields such as pediatric cardiology is still beyond the capability of commercially available AI chatbots.[4]

Numerous researchers have studied and published various AI applications in congenital heart disease (CHD) in the last decade.[1,3] However, the transition of any new technology from the research stage to routine clinical practice is fraught with challenges. Concerns regarding safety, privacy, data security, and ethical and medicolegal approvals must be addressed before any new technology can be applied to and accepted in clinical medicine. As these models will all require uploading patient data to the cloud for analysis, cybersecurity also needs to be robust to protect against cyber-attacks such as the one on the All India Institute of Medical Sciences, New Delhi, in November 2022, which temporarily halted access and use of the hospital information system. AI models require immense computing power and, consequently, require expensive infrastructure and personnel training. This is a significant challenge in developing and low- and middle-income countries, where it might be economically more prudent to train cardiac specialists than to invest in AI infrastructure. Any promising AI model needs to be developed with vast amounts of raw data and clinical oversight to help the model learn the interpretation of the data. Next, the model must be validated with more blinded data to ensure correct analysis and results. As pediatric cardiology encompasses a heterogeneous group of CHDs with various treatment modalities and often more than one standard treatment approach for the same CHD based on clinician and institutional preferences, generating sufficient datasets to train and validate AI models is challenging.[1] The only solution to this hurdle is a multicenter and international collaboration to design and perform AI-related studies.

In this issue of APC, Torshizi *et al*. describe their preliminary observations on the successful use of an AI-based model for automatic, noninvasive, and real-time estimation of blood potassium levels from single-lead electrocardiogram (ECG) signals. If proven in larger studies, the algorithms could be incorporated into smartwatches and implantable devices in high-risk patients.[5] The publication is very different from the usual published articles and may be difficult for the clinician to understand and apply. The practicing clinicians need to understand the nuances of research in AI and the varied methodologies.

Among published studies on AI in pediatric cardiology, only some have been implemented into mainstream clinical medicine. One such model we came across is from the Mayo Clinic, USA, where researchers used a convolutional neural network and supervised learning with binary outcome variables to find an association between ECG changes and left ventricular (LV) dysfunction. Henceforth, all ECGs done at the hospital are run through this model. If the system detects any ECG evidence of reduced LV ejection fraction ($<50\%$), the patient undergoes further testing with echocardiography and a cardiology consult.[6] A similar study was recently published from Boston Children’s Hospital and Mount Sinai Hospital, where a convolutional neural network was trained on paired ECG–echocardiograms from patients ≤ 18 years of age without major CHD to detect greater than mild LV dysfunction, hypertrophy, and dilation.[7]

Apart from the logistic hurdles of developing and introducing AI models into clinical pediatric cardiology, there are also essential aspects of clinician and regulatory acceptance. Introducing any AI model into clinical practice at a level where we can reduce human oversight on the decisions generated by the AI system will require years of overlapping clinician and AI decision-making to ensure that the AI model is reliable and safe for patient care. In the present era, most pediatric cardiologists are unfamiliar with data science, and it will take considerable time and effort for them to understand how AI models arrive at a decision and, more importantly, to trust the AI model's recommendation, especially if it diverges from their personal experience or practice. Perhaps, in preparation for the future, the first step to address this issue should be to introduce chapters and training on "AI in Medicine" into the standard educational curriculum for medical students and DM/DNB Pediatric Cardiology residents.[3] Furthermore, implementing AI models into clinical practice will require regulatory and legal approvals from national agencies such as the National Medical Commission, the Central Drugs Standard Control Organization, and the Ministry of Electronics and Information Technology.

With these obstacles, AI models should be initially developed and implemented in areas where they help solve a relevant clinical problem and potentially positively impact patient care. Hence, applications tailor-made to different countries and scenarios may have a more significant impact and be more quickly adopted than generalized universal health-care AI applications.

SUGGESTED USES OF ARTIFICIAL INTELLIGENCE IN INDIAN PEDIATRIC CARDIOLOGY

In the Indian scenario, we believe our field can benefit from AI models in a few specific situations.

Screening and early detection of congenital heart disease

Echocardiography is an operator-dependent technique, and missed or incorrect diagnosis can delay timely referral, patient transfer, and initiation of treatment. With the widespread availability of echocardiography machines even in tier 2 and tier 3 cities, perhaps we can develop image processing algorithms where standard views of fetal ultrasound scans done by radiologists or obstetricians and transthoracic echocardiograms done by cardiac sonographers and adult cardiologists can be screened by AI models to detect those patients with CHD.[1,8-11] Then, those positive cases can have a formal assessment and detailed evaluation by a pediatric cardiologist.

Pediatric cardiac critical care

The pediatric cardiac ICU generates large volumes of data from ECGs, invasive arterial and venous pressure lines, ventilatory airway pressures, urine output, and arterial blood gases. In most Indian ICUs, finding, training, and retaining experienced nursing staff and junior doctors is challenging. Cardiac arrest following pediatric cardiac surgery is estimated to range between 2.6% and 6% of patient encounters and results in significantly higher mortality regardless of the complexity of surgery.[12] An AI model that could help detect subtle clinical deterioration in a postoperative patient before obvious clinical signs such as hypotension, desaturation, and cardiac arrest will enable early interventions to smoothen the postoperative course and improve outcomes. Kwon *et al.* published regarding a deep-learning algorithm (deep learning-based early warning system) that used four vital signs (systolic blood pressure, heart rate, respiratory rate, and body temperature) to predict cardiac arrest in patients in a multicenter study with a higher sensitivity and a lower false-positive rate compared to traditional modified early warning systems.[3,13] This model was applied retrospectively to detect > 50% of patients with cardiac arrest 14 h before the event and 78% of cardiac arrests 30 min before the event. A review by Olive and Owens also discussed predictive AI models that can lead to earlier detection of patients at risk for clinical deterioration and improve care in the pediatric cardiac intensive care setting.[3,12]

Analysis and interpretation of arrhythmias

Specific diagnosis of atrial and ventricular arrhythmias and starting appropriate treatment is beyond the training of most pediatricians and usually requires a pediatric cardiology or electrophysiology consult. An AI model trained with thousands of diagnosed and labeled ECGs could quickly and correctly diagnose the arrhythmia and suggest the correct and optimum antiarrhythmic medications for the patient. In India, Tricog Health, a startup founded in 2014, markets instaECG™, a device that enables taking ECGs at remote locations and uploading these into the cloud, where preliminary interpretation is made with AI algorithms, followed by checking and reporting by cardiac specialists. Hannun *et al.* used a deep neural network to classify a range of arrhythmias from single-lead ECGs with high diagnostic performance similar to cardiologists in terms of sensitivity and positive predictive value.[14]

Clinical decision-making in complex congenital heart disease

Finally, AI models can help offer specific insights into the clinical decision-making for the optimum treatment approaches for complex CHD, such as borderline left ventricles, late arterial switches for transposition of great arteries with intact ventricular septum, complex atrioventricular canals for two ventricle conversions, and double outlet right ventricle for complex intraventricular tunneling. Evidence-based medicine, supported primarily by randomized controlled trials (RCT), is the cornerstone of practice improvement in modern medicine.[15] Yet, in pediatric cardiology, RCTs are relatively few, are often suboptimally designed, and are underpowered for various reasons, including cost, poor follow-up, and the heterogeneity of the patients being studied.[15,16] Hence, clinical decision-making in pediatric cardiology is frequently influenced by heuristics, intuitions, and biases, with wide variation in treatment approaches depending on clinician training, experience, and institutional practice.[8,17] Here, the AI model could potentially analyze the published world literature and what works for the surgeon and center where the model is being applied. An exciting concept Van den Eynde *et al*. discussed is "Medicine Based Evidence," which entails using big data and deep learning along with biological, clinical, social, behavioral, and environmental data collected over a lifetime to build a comprehensive patient profile.[18] Whenever a physician needs to decide about a patient's treatment plan, a library of patient profiles can be interrogated, along with their responses to various pharmacological treatments and procedures. This can help predict the effect of a specific treatment decision on the index patient.[18] Eventually, mechanistic models of cardiac physiology can be combined with statistical models derived from randomized control trials to create a "digital twin" of the patient. This can predict the patient's response to pharmaceutical treatment and/or medical device/surgical interventions, the ultimate aim of "precision medicine."[1,19] In the future, these digital twins can be used to simulate how a coarctation stent, or transcatheter pulmonary valve, will function in the long-term and even help in the selection of the most appropriate stent/valve for that patient. We foresee a future where precision cardiac therapy can be modeled and simulated like wind tunnel experiments today for automobiles and aircraft. Hopefully, this will help eliminate physician and institutional biases and the learning curve of decision-making that any clinician undergoes during training and early practice.

To conclude, AI today is still in the research phase only for applications related to pediatric cardiology. However, research is promising, and there is clear evidence that AI can improve outcomes in pediatric cardiac practice. In the next decade, pediatric cardiac professionals will benefit from formal AI and data science training and better collaboration with data scientists and computer scientists to develop and implement AI models in mainstream pediatric cardiac care.

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Submitted: 19-Apr-2024 **Revised:** 15-May-2024
Accepted: 20-May-2024 **Published:** 20-Jul-2024

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DOI:
10.4103/apc.apc_72_24

How to cite this article: Sen S, Ramakrishnan S. Artificial intelligence in pediatric cardiology: Where do we stand in 2024? Ann Pediatr Card 2024;17:93-6.