



Review Article

Integration of AI with Fetal Echocardiography and MRI for Prenatal CHD Detection: An Updated Review of the Literature

Shamsi Ghaffari^{ID}

Cardiovascular Research Center, Tabriz University of Medical Sciences, Tabriz, Iran

Article info

Article History:

Received: February 19, 2026

Revised: June 20, 2026

Accepted: July 4, 2026

published: August 25, 2026

*Corresponding Author:

Shamsi Ghaffari,
Email: shamsi.ghaffari@gmail.com

Abstract

Detection and diagnosis of congenital heart disease during fetal echocardiography and magnetic resonance imaging are other areas that artificial intelligence has transformed the prenatal healthcare system. This review discusses the application of AI in these imaging approaches with regard to the progress achieved in automated image enhancement and segmentation, as well as the detection of abnormal features. Advanced AI models, especially the deep learning algorithms, have demonstrated encouraging outcomes in terms of diagnostic accuracy, human error reduction, and quicker decisions. In spite of these developments, some challenges have been left, such as data quality, complexity of the algorithm, and the fact that large computational resources are required. There are challenges regarding clinical acceptance, regulatory issues, and the integration of AI into existing workflows. Nevertheless, the opportunities of AI, in particular, custom pregnancy care and the availability of more complex diagnostics, are promising. Further advances in the field of multi-modal AI integration, transfer learning, and ongoing enhancement of algorithms should contribute to better AI application in prenatal CHD detection. The advancement of AI technologies has the potential to transform prenatal diagnostics, leading to improved outcomes for both mothers and newborns. The present review emphasizes the need to conduct further research, take ethical factors into account, and establish effective and consistent regulatory frameworks to guarantee successful and fair usage of AI in clinical practice.

Keywords: Artificial intelligence, Fetal echocardiography, MRI, CHD

Introduction

One of the most prevalent types of congenital anomalies is congenital heart disease (CHD), with an incidence of about 8 in every 1000 live births worldwide. It causes a considerable percentage of neonatal mortality and morbidity. The prevention of CHD in early stages and especially in prenatal stages can greatly enhance the outcomes of postnatal stages through timely intervention and informed judgments. The early detection and identification of fetal heart anomalies can enable health professionals to be ready should the process of labor and birth introduce complications and also prepare the new mother to receive the immediate care that might be necessary.^{1,2}

Fetal echocardiography (FE) is a special type of ultrasound imaging that has been widely used as the basis of prenatal evaluation of congenital heart defects. It allows clinicians to visualize the developing fetal heart, including its anatomy and function, even during the early stages of pregnancy. Nevertheless, fetal echocardiography has such weaknesses as its reliance on the operator, the high learning curve of this procedure, and the impossibility of visualizing some anatomical structures, especially when using an obese mother or fetus in a particular position.

Furthermore, despite the high detection rate of CHD using FE, the method is not infallible, and false diagnoses may be missed, particularly in the case of complicated heart defects or when the defects are mild.^{3,4}

Magnetic Resonance Imaging (MRI) is a complementary method of fetal echocardiography, where images of fetal structures are provided in detail and with high resolution without the application of radiation.⁵ Fetal MRI may also prove to be helpful in cases of complicated congenital heart defects that are difficult to identify with ultrasound (involving the great vessels or complex intracardiac anatomy). The application of MRI as a method of prenatal cardiac evaluation, however, remains comparatively small because of its higher cost and demand for specialized equipment and the fact that it may not be so prevalent as the ultrasound.⁶

Over the last few years, the process of implementing artificial intelligence (AI) and machine learning (ML) algorithms into medical imaging and prenatal diagnostics, in particular, has increased significantly. AI has already shown great potential in improving the accuracy and efficiency of medical imaging interpretation. AI can be used to automate the process of analysis of fetal echocardiographic and MRI images, thereby reducing



the variability of interpreted results, aiding clinicians to identify hidden anomalies, and accelerating the diagnostic procedure. Machine learning algorithms and deep learning methods, in particular, have been shown to be effective specifically in processing complex image data and feature extraction that would not be noticeable to a human observer.⁷

The integration of AI and fetal echocardiography and MRI can transform the diagnosis of CHD during the prenatal stage. Through the enhancement of the functions of these imaging modalities, AI can be used to increase the accuracy of diagnostic results, decrease the level of human error, and, eventually, enhance clinical outcomes among the affected infants. Moreover, the use of AI can offer a chance to create predictive models, allowing clinicians to evaluate the extent of defects, predict possible complications, and design interventions in line with it.⁸

The purpose of this review article is to examine the current developments in the field of AI integration with fetal echocardiography and MRI to recognize prenatal CHDs. The emphasis will be on recent studies and advances in the area and the difficulties and prospects related to the use of AI in clinical practice.^{9,10} This paper will present the ongoing trends in AI applications in prenatal heart disease detection through an overview of the latest research and developments and will give the insights to the future of this quickly growing field. The potential role of such technologies in clinical practices and their ability to deliver more accurate diagnoses, better prenatal care, and eventually better outcomes in infants with congenital heart defects will also be discussed in the review.

Literature Search Methodology

A narrative literature review was conducted to identify relevant studies investigating the application of artificial intelligence (AI) in fetal echocardiography and fetal magnetic resonance imaging (MRI) for the prenatal detection of congenital heart disease (CHD). Electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were searched for articles published between January 2019 and January 2025.

To find the right studies, we used a search strategy that combined keywords and Medical Subject Headings terms. We looked for things like “artificial intelligence”, “machine learning”, and “deep learning”, as well as terms related to fetal imaging and diagnosis, such as “fetal echocardiography”, “fetal cardiac ultrasound”, “fetal MRI”, “prenatal diagnosis”, and “congenital heart disease”. We also manually checked the reference lists of relevant articles to see if we could find any other studies that might be useful.

To be considered for this study, research had to focus on creating, testing, or using artificial intelligence techniques for taking pictures of unborn babies’ hearts and detecting heart defects. We looked at original research, reviews of lots of studies, analyses that combined results from many studies, and methodological studies that could be used in real medical settings, as long as they were written

in English. We didn’t include summaries of talks given at conferences, opinion pieces, repeated publications, or studies that weren’t about taking pictures of unborn babies’ hearts.

The selected literature was reviewed and synthesized narratively, with particular emphasis on diagnostic performance, clinical applicability, implementation challenges, and future directions of AI-assisted prenatal CHD detection.

To make sure we get as much information as possible, we used many databases, set clear rules for what we were looking for, and carefully checked the lists of sources. This way, we could be sure that our search was thorough and that others could repeat what we did.

Literature Review

Current Applications of Artificial Intelligence in Fetal Echocardiography

Fetal echocardiography has found extensive application in the identification of congenital heart disease at the prenatal stage because of its noninvasive nature and real-time imaging. Nevertheless, the weaknesses of conventional echocardiography, such as being operator-dependent and having discrepancies in image interpretation, have prompted the growing interest in the application of artificial intelligence to this field. AI technologies, especially machine learning and deep learning (DL), have been implemented to enhance the accuracy and efficiency of fetal echocardiography in a variety of ways.¹¹

Automated Detection of Common Heart Defects

Among the most significant uses of AI in fetal echocardiography, it is possible to note the automatic identification of typical congenital heart issues, e.g., ventricular septal defects (VSDs), atrial septal defects (ASDs), and patent ductus arteriosus (PDA). An overview of a deep learning method called Convolutional Neural Networks (CNNs) has been utilized to examine ultrasound images to identify structural abnormalities. The models are trained with massive amounts of labeled images and can automatically recognize features that are signs of heart defects with the required degree of accuracy.¹²

Recent papers have confirmed that deep learning can be very effective in the discrimination of normal and abnormal cardiac structures. As an example, Arnaout et al. (2022) have shown a model that was able to screen CHD on 18 standard views with an area under the curve (AUC) of 0.99 with superb performance that matched that of the experts. Moreover, multi-view models, including the one created by Zhang et al. (2022), have obtained accuracy in the classification of major types of CHD, reaching over 95 percent.¹³

New studies on using artificial intelligence in fetal heart imaging are getting a lot of attention, and they’re showing even more proof that this technology is really helpful. For example, Suha and their team looked at how AI can improve the detection of heart defects in babies by using it with echocardiography. They found that AI makes it

easier to spot these defects and tell them apart, which is a big deal. The researchers think that AI could help doctors catch these problems early on, and it could also be a big help to doctors who are still learning how to do these screenings. This is especially important for routine checks on unborn babies.¹⁴

Real-Time Heart Rate Monitoring and Functional Assessment

Besides structural abnormality, AI has also been applied to measure the functional aspects of the fetal heart, which include the heart rate variation and the pattern of blood circulation. Machine systems that are trained to analyze Doppler ultrasound data are able to examine fetal heart rate and blood flow in real time. It assists in detecting where deviant hemodynamic changes are suggestive of underlying faults of the heart or other fetal abnormalities. The models of AI can also help assess the effectiveness of the work of the fetal heart as a whole, which is crucial to assessing the severity of CHD and determining interventions.^{15,16}

AI-Assisted Image Processing in Fetal Echocardiography Enhancing Image Quality and Reducing Noise

Sometimes the fetal echocardiography images may be of poor-quality owing to maternal obesity, fetal position, or noise and artifact. AI has demonstrated significant potential in improving the quality of images by eliminating noise and enhancing the quality of ultrasound images. One type of deep learning model, known as generative adversarial networks (GANs), has been studied to enhance the clarity of fetal echocardiographic images so that the clinician can more easily detect and interpret heart abnormalities.¹⁶

Vollbrecht et al. (2024) studied the use of the GAN model to improve the quality of fetal echocardiography images by removing the noise and artifacts. The model also contributed greatly to enhancing the clarity of the images, making the structures of the fetal heart better visualized. The application finds special application in the clinical setting, where the quality of the imaging is necessary to make accurate diagnoses but is not always possible because of technical restrictions.¹⁷

Automatic Segmentation and Landmark Detection

The key fetal cardiac structures include the heart chambers and the great vessels, and their segmentation is a very important process in the analysis of fetal echocardiography images. This has been traditionally done manually and thus is time-consuming and also prone to operator inconsistency. To make the process of image segmentation automatic, AI models, especially CNNs and U-Net architectures, have been created to make the analysis of images more time-efficient, as well as to make the results more consistent.¹⁸

Wang et al. (2021) applied a CNN-based model to automatically segment fetal heart structures in an echocardiographic image. The heart chambers were

delineated correctly by the AI system, and this can be a difficult task, given the small size and complicated structure of the fetal heart.¹² AI-assisted segmentation tools can be used to make the process of fetal echocardiography more efficient by simplifying the workflow, especially when in a busy clinical setting.

Artificial Intelligence-Assisted Diagnosis and Prediction of CHD in Fetal Echocardiography

AI-Assisted Diagnosis of Congenital Heart Disease

AI has also been used in the diagnosis of congenital heart disease by analyzing large volumes of fetal echocardiography images and identifying tiny anomalies that a human expert can fail to notice. Machine learning algorithms like random forests and support vector machines (SVMs) have been used to classify images based on the availability of cardiac defects. These models are able to distinguish between normal and abnormal fetal heart structures since they were being trained on labeled datasets.¹⁹

In one article by Yang et al. (2023), the SVM model was trained to detect fetal echocardiography shots as belonging to specific categories depending on the existence of common heart diseases. The accuracy of the model exceeded 90, and such performance is similar to that of skilled clinicians.²⁰ This shows how AI can be used in offering diagnostic assistance, particularly in organizations where trained sonographers or cardiologists are insufficient.

Predicting the Severity of CHD

In addition to diagnosis, AI models have been applied in predicting the severity of congenital heart disease using the characteristics of the fetal heart. The AI algorithms can be used to identify the probability of adverse outcomes, including heart failure or postnatal surgical intervention, by examining various features in the echocardiographic images, including the chamber size and the presence of valve defects.²¹

Indicatively, a paper by Liu et al. (2024) created an artificial intelligence-based system that was capable of estimating the severity of CHD in fetuses by examining the sizes of the heart chambers and the major vessels. The system could accurately predict whether a fetus would require postnatal surgery or treatment. The predicted ability can prove to be priceless in prenatal counseling and planning, where the clinician and the family can make relevant decisions about the management of the pregnancy and delivery.²¹

Integrating AI with Clinical Workflow

With the ongoing development of AI technologies, the concept of introducing them into the clinical workflow is becoming more popular. AI models can help clinicians make real-time decisions in the course of the examination and present alerts and recommendations concerning the analysis of the fetal echocardiography images. Such integration is capable of improving the quality of care

provided to pregnant women, as well as decreasing the number of diagnostic errors and, subsequently, decision-making.^{3,11,22}

As an illustration, a real-time AI-based system was designed in a study by Athalye et al. (2024) to help sonographers during fetal echocardiography. The system also offered real-time feedback of image quality and areas of concern that could portray some heart defects. Such an AI-supported tool can make the process of fetal echocardiography more efficient and trustworthy, which will eventually enhance the results for the mother and fetus.²²

More proof that AI can be used in real-world medical settings came from a study done by D'Alberti et al. in 2025. They looked at lots of research on using AI to help with ultrasound tests on unborn babies' hearts. What they found was that AI was really good at diagnosing problems, and it did this consistently across many different studies. This suggests that using AI to help with these tests could make diagnoses more consistent and accurate. However, the researchers also said that before AI can be widely used in clinics, more studies need to be done in many different hospitals to make sure it works well in all settings.²³

Numerous studies have described a benefit for AI-assisted fetal cardiac imaging in diagnostic accuracy and in the workflow efficiency, but the results should be interpreted from the context of study design and methodology for validation. A number of published models have been developed and validated in retrospective datasets from individual institutions, and relatively few have been externally validated, multicenter assessed and/or tested in the forward-looking clinical setting. The published performance data may not therefore be a true indicator of clinical performance. Robust validation strategies should be emphasized in future studies to strengthen the generalizability and clinical applications of AI systems for prenatal CHD detection.

AI Applications in Fetal MRI for CHD Detection

Enhancing MRI Image Quality

Fetal MRI has become an effective diagnostic method in the diagnosis of intricate congenital heart disease during the prenatal phase, especially where fetal echocardiography cannot offer adequate clarity or resolution.⁶ Although fetal echocardiography has been the most common imaging method in the evaluation of fetal heart defects, MRI has gained popularity for its capability to provide high-resolution images of the heart as well as vessels.⁵ Application of artificial intelligence in fetal MRI is exceptionally promising to elevate the level of diagnostic accuracy, shorten the interpretation time, and improve clinical decision-making overall.

Among the main uses of AI in fetal MRI, there is the process of image quality improvement. Although MRI is a high-resolution technique, fetal scans are frequently affected by low signal-to-noise ratios (SNR), motion artifacts, and fetal positioning problems. Such issues can affect the quality of the images to the extent that the

structure and functioning of the fetal heart will be hard to evaluate properly. Artificial intelligence, and especially deep learning algorithms, such as CNNs and GANs, have been shown to effectively deal with these problems through noise reduction, resolution enhancement, and motion artifact removal. Raw MRI data can be improved by AI algorithms so that the image of a fetal heart appears better and its details become more convenient and easier to analyze, even in problematic cases.²⁴

Deep learning has specifically provided solutions to the problem of noise in the fetus MRI. It is important to note that Vollbrecht et al. (2024) concluded that deep learning-based denoising was much more effective than traditional compressed sensing methods and, therefore, enhances the quality of fetal cardiac cine MRI diagnosis.

Automated Segmentation of Fetal Cardiac Structures

The application of AI in automating fetal cardiac structure segmentation in MRI has been achieved. Historically, segmentation is done manually by drawing out the important heart structures, i.e., left and right ventricles, atria, and great vessels. This is a time-consuming process that relies on the skill of the clinician. Nevertheless, AI architecture-based segmentation models, particularly the U-Net and CNN-based ones, have proven to be extremely precise in automatically detecting and demarcating these structures. This automation, in addition to accelerating the process of analysis, also minimizes the possibility of human error. These qualities of AI models to provide reproducible and reliable segmentation of key cardiac features are guaranteed by the capacity to react consistent with the skill level of the operator.²⁵

Automated cardiac structure segmentation is still an important part of quantitative analysis. Patey et al. (2025) were able to create a deep learning-based algorithm to robustly separate the fetal heart in motion-corrupted MRI images to enable 3D visualization and functional evaluation.

Detection of Abnormal Cardiac Features

Besides segmentation, abnormal cardiac features have been recognized in fetal MRI scans by applying AI.⁶ There are several other congenital heart diseases like hypoplastic left heart syndrome (HLHS), tetralogy of Fallot, and transposition of the great arteries (TGA), which are subtle and, in many cases, may not be revealed in the traditional imaging modalities. Using a huge amount of labeled MRI images, AI systems can identify patterns that are indicators of these defects. Indicatively, AI models have been demonstrated to identify malformations of the great vessels, intracardiac defects, and other abnormalities of the outflow tract, which are not easily noticed by human experts. This is especially essential in the diagnosis of complex CHDs in order to be able to plan any intervention during postnatal care.^{20,26}

AI-Assisted Prediction of Disease Severity And Outcome

A second potential use of AI in fetal MRI is prediction

of disease severity and possible outcomes. According to the examination of the different cardiac structures in the MRI images—including the volume of heart chambers, the existence of valvular or vascular defects, and blood circulation—AI algorithms can forecast the intensity of the defect and the risk of postpartum complications. This predictive ability enables clinicians to be more prepared to provide postnatal care, such as the need to realize that surgery will be required at once or that future surveillance will be required in the long term. Moreover, AI models will assist in making more knowledgeable choices regarding the pregnancy management and birth, offering crucial information regarding the risks involved in the various forms of CHD.^{7,24}

Multi-Modal AI Integration (Combining MRI and Echocardiography Data)

The combination of AI and fetal MRI data with echocardiography is also becoming popular. With the

integration of the capabilities of these two imaging modalities, AI can provide a more detailed examination of the fetal heart. Fetal echocardiography is very useful in the visualization of the general structure of the fetal heart, whereas MRI is better able to offer detailed structural imaging. The images of MRI and echocardiography can be processed simultaneously by AI that uses the strengths of each of these modalities to improve the diagnostic process. As an example, AI has been created to integrate ultrasound and MRI imaging, enhancing the detection of fine or complicated heart defects that might not be fully resolved using either of the imaging modalities. Such a multi-modal method can assist in making sure that the assessment of the fetal heart is more accurate and comprehensive.³

There have been great improvements both in diagnoses and in the workflow because of the use of artificial intelligence in prenatal imaging. Table 1 is a detailed overview of the most recent important studies examining

Table 1. Summary of key studies on AI applications in fetal echocardiography and MRI for CHD detection

Author(s) & Year	Study Objective	Key Findings	Reference
Suha et al. (2025)	To review the AI-enhanced echocardiographic detection of CHDs in the fetus.	AI-enhanced echocardiography shows promise in improving the detection and classification of fetal CHDs, potentially aiding in earlier and more accurate diagnosis.	14
D'Alberty et al. (2025)	To systematically examine the current literature on the diagnostic performance of AI-enabled prenatal cardiac ultrasound.	The systematic review highlights the high diagnostic performance of AI-enabled prenatal cardiac ultrasound for CHD detection, though more prospective trials are needed.	23
Patey et al. (2025)	To research the prenatal detection of CHDs using deep learning-based AI models.	Research showed that deep learning-based or more general AI models can support the detection of fetal CHDs more rapidly than humans, suggesting a potential to improve screening efficiency.	27
Aydin & Mustafa (2025)	To evaluate the role of AI in fetal medicine, including opportunities, evidence, and challenges.	Peer-reviewed studies report high accuracy for AI models in identifying CHDs, but most tools remain investigational due to limited external validation, lack of explainability, and poor integration with clinical workflows.	28
Liu et al. (2024)	To review applications of AI-powered prenatal diagnosis for CHD.	AI models show high accuracy in CHD detection, view classification, and segmentation. The integration of AI with standard ultrasound can enhance diagnostic consistency and efficiency.	21
Ma et al. (2024)	To discuss the role of AI in automating and standardizing the display of diagnostic sections of the fetal heart.	AI can automate and standardize the display of each diagnostic section of the fetal heart, contributing to more accurate and consistent CHD diagnosis.	3
Vollbrecht et al. (2024)	To evaluate deep learning (DL)-based denoising for fetal cardiac cine MRI.	DL-based denoising outperformed conventional compressed sensing (CS) for fetal cardiac cine MRI, significantly improving image quality and potentially enhancing diagnostic capabilities.	17
Athalye et al. (2024)	To assess the performance of a deep learning model for prenatal CHD screening.	The deep learning model demonstrated high performance in automated image recognition from ultrasound for CHD detection, showing potential for clinical application.	22
Ramirez Zegarra & Ghi (2023)	To review the current applications, challenges, and future prospects of AI in fetal ultrasound imaging.	The review highlights that AI excels in image quality assessment, view classification, and CHD detection, but emphasizes the need for large annotated datasets and rigorous clinical validation.	29
Yang et al. (2023)	To classify normal versus abnormal fetal heart ultrasound images and identify ventricular septal defects (VSDs) using deep learning based on the four-chamber view.	The deep learning model demonstrated high accuracy in classifying cardiac status and identifying VSDs, proving effective as a screening tool for structural abnormalities.	20
Arnaout et al. (2022)	To train and test a deep learning model to screen for CHD across 18 different standard fetal echocardiography views.	The model demonstrated excellent performance in distinguishing normal from abnormal hearts across all views, with an AUC of 0.99. It could also identify specific view-dependent CHD features.	13
Zhang et al. (2022)	To develop a multi-view deep learning framework for the automated diagnosis of specific categories of CHD.	The model, which analyzed multiple standard views simultaneously, achieved an overall accuracy of 95.4% in classifying five major CHD types, outperforming models that used single views.	12
Day et al. (2021)	To review the potential uses and ethical considerations of AI in fetal cardiology.	AI has the potential to improve CHD detection rates, provide more accurate prognoses, and enable automatic quantification of cardiac function. However, ethical and governance concerns must be addressed before mainstream clinical use.	30

the role of AI in fetal echocardiography and MRI. These papers indicate the advances made in automated view classification, image quality improvement, and the detection of complex CHD. On the whole, this literature highlights the promise of AI models to achieve or even surpass the performance of the experts in clinics.

Challenges and Opportunities

Technical Challenges in AI for Prenatal CHD Detection

Although AI has great potential to enhance detection of CHD in pregnancy, there are some technical challenges. These are mainly connected with the quality of the data, the complexity of the algorithms, and the computation needed to handle large amounts of data.

Data Availability and Quality

The absence of annotated datasets of large size and high quality is one of the largest challenges to the use of AI in fetal echocardiography and MRI. Deep learning algorithms, particularly those based on CNNs and other highly complex models, need large volumes of labeled media to be trained. When working with prenatal imaging, it is difficult to find adequate datasets since the process of imaging is complicated, and the scans can be affected by maternal conditions, fetal position, and quality of images. Besides, fetal heart defect labeling is a highly skilled process, and mislabeling may have an impact on the AI model.²⁴

Imaging Artifacts and Variability

Fetal MRI and echocardiography have motion artifacts, noise, and imaging condition variations. As an illustration, fetal movement, maternal body type, and disparities in imaging equipment will contribute a lot of noise to scans. Despite the success of AI models in improving image quality and minimizing noise, they exhibit weaknesses in the ability to cope with variability in the images. Models that are trained on data from a single population or imaging setting may not be generalizable to other populations, creating problems with applying AI tools in a variety of clinical settings.²⁸

Computational Demands

The requirements of training AI models on large datasets involve a lot of computational power. Deep learning models may require many hours of training and the availability of specialized hardware, such as Graphics Processing Units (GPUs), to be used, particularly where the model is trained on high-resolution MRI scans of fetuses. Such computational requirements could be an obstacle to wide clinical use, particularly in resource-constrained environments where such equipment might be absent.²⁷

One thing to note is that you need to differentiate between the models that are considered as proof of concept and the models that are clinically proven. Numerous studies reported in the current literature claim good diagnostic performance in laboratory research settings,

but few AI tools have been validated in prospective clinical settings or implemented in clinical practice. Whereas, there is a need for external validation, multicenter testing, regulatory approval and workflow integration, and clinician acceptance if this is meant for clinical use. Although the overall results of the current research are encouraging, there are still many potential applications for the detection of CHD in the prenatal period that are still in development or early trials that rely on AI.

Clinical and Implementation Challenges

Clinical and implementation challenges also play a major part in integrating AI in prenatal care, in addition to technical difficulties.

Trust and Acceptance Among Clinicians

The adoption of AI in clinical practice must be embraced by the medical community, especially those who became used to interpreting imaging data by hand. Resistance to implementing AI tools can also occur, particularly when clinicians are not sure that the tools are reliable or feel like AI is taking away their professional knowledge. The credibility of AI models is often challenging to gain unless these systems are properly tested and shown to be more effective than conventional ones or yield significant advantages in terms of diagnostic quality and efficiency.¹⁵

Regulation and Ethical Concerns

With the growing role of AI instruments in the decision-making domain, particularly in sensitive fields such as prenatal care, the issues of ethics and regulations take center stage. Issues about the transparency of AI models, the accountability of clinical decisions, and the safety of patient data should be discussed. Moreover, regulatory organizations, including the FDA or the CE in Europe, should make sure that AI systems are safe, effective, and free of bias prior to their approval for clinical use. Formulating specific principles regarding how AI can be applied to clinical practice is a challenging task.³¹

Integration into Clinical Workflow

The implementation of AI in the current clinical workflow is not a direct one. Implementation of AI tools should be done with close attention to how it fits in the existing workflow of fetal echocardiography and MRI departments. These should be simple to use, integrate with the current software systems, and be able to deliver the real-time feedback without interrupting the workflow of the clinician. Moreover, the implementation of AI systems may be quite expensive due to the prices of software, hardware, and training, which might be a huge burden on certain healthcare institutions.⁷

Aydin and Mustafa took a close look at how AI is being used in fetal medicine in 2025. They found that even though many AI models seem to be very good at diagnosing problems, they are not being used much in real-life medical settings. There are several reasons for this, including that these models have not been tested

enough outside of the labs where they were created, it's hard to understand how they make their decisions, and it's not clear how they can be used in everyday medical work. This shows that there is a big difference between how well these models work in theory and how useful they are in actual medical practice.²⁸

Opportunities in AI for Prenatal CHD Detection

The development of AI in the diagnosis of congenital heart disease, despite the difficulties, can offer many opportunities to enhance the process of prenatal care and patient outcomes.

Improved Diagnostic Accuracy

The diagnostic accuracy can be greatly enhanced by AI, as it will help to eliminate the human factor and surmount the shortcomings of conventional imaging techniques. Deep learning architectures are able to detect minor anomalies in fetal echocardiography and MRI images that can be overlooked by human specialists. Through the large volumes of data, AI models will be able to identify patterns that are perhaps too complex to be identified by the human eye, resulting in more timely and precise diagnoses.^{9,18}

Faster Decision-Making

AI can be used to streamline the diagnostic process, offering real-time fetus image analysis. This speed enables clinicians to make faster decisions on how the pregnancy should be handled. As an example, AI may, by default, identify images that are abnormal, identify regions of interest, or propose possible diagnoses, saving clinicians time to interpret images and instead spend time with patients. This might be especially useful in the hectic clinical practice or during emergencies when quick judgments are paramount.¹¹

Personalized Prenatal Care

The AI might allow the personalization of prenatal care by providing diagnostic and treatment plans that are adapted to the specific needs of a particular patient. Based on the study of different data points, including fetal heart structure, maternal health, and genetic factors, AI systems may be useful in predicting the possibility of developing specific congenital heart defects and prescribing individual intervention plans. This may result in more focused interventions and better outcomes for both babies and mothers.^{21,27}

Expanding Access to Advanced Diagnostics

Artificial intelligence has the potential to expand access to advanced prenatal cardiac diagnostics, particularly in underserved and resource-limited regions where access to fetal cardiology specialists is restricted. AI-assisted image acquisition and interpretation tools can support less-experienced healthcare providers in identifying suspected congenital heart abnormalities and facilitate timely referral to specialized centers. Furthermore, cloud-based

AI platforms and telemedicine networks may help reduce geographic disparities in prenatal healthcare by enabling remote consultation and expert review of fetal cardiac imaging. As these technologies become more accessible and cost-effective, they may contribute to more equitable prenatal CHD screening and improved maternal–fetal outcomes worldwide.^{24,32}

Future Directions

Advances in AI Algorithms

The future of AI in prenatal heart disease detection is the constant enhancement of machine learning and deep learning algorithms. With more advanced AI models, the quality of analysis of complex and high-dimensional imaging data will be even more advanced. It is expected that in the future more data will be used, as in multi-modal data (a combination of MRI, echocardiography, and even genetic information) that will give a more comprehensive picture of the fetal heart. Such combined AI systems may provide diagnostic accuracy never seen before, boosting the rates of early detection of complicated congenital heart conditions, which are hard to detect using existing technologies.^{24,26}

Patey et al. (2025) highlighted the growing role of deep learning-based image and video analysis in prenatal CHD detection through the multicenter CAIFE initiative. Their work demonstrated the feasibility of large-scale international collaboration for developing robust AI models and emphasized the importance of diverse datasets for improving model generalizability and reducing algorithmic bias.²⁷

Transfer Learning and Data Augmentation

The transfer learning and data augmentation techniques are among the prospective opportunities in the future. These techniques will be useful in addressing the shortage of annotated data with the help of existing pre-trained models on different domains or generating synthetic training data to expand small datasets. This will enable better construction of AI models that are highly accurate even in situations where data is sparse.³¹

Integration with Other Diagnostic Modalities

Although fetal MRI and echocardiography are already complementary to each other, there is a possibility of further integration with other diagnostic modalities in the future. As an illustration, AI-based analysis of fetal MRI with the help of genetic screening data or maternal health records could contribute to a more accurate identification of the probability of congenital heart disease, its severity, and possible results. This integrated approach would provide more accurate and detailed risk assessments to the pregnant parents.³¹

Ethical and Regulatory Developments

As AI-based systems continue to take on a role in prenatal care, both ethics and regulatory systems will be required to undergo potential changes to guarantee their safe and

fair usage. Trust of healthcare providers and patients will be dependent on the development of AI models that are transparent, interpretable, and not prejudiced. Regulators should also strive to establish norms that place AI models as not only efficient but also moral and reasonable, especially when prenatal care is involved in sensitive matters.¹⁵

AI-Enabled Remote Monitoring and Telemedicine

Remote monitoring and telemedicine are two of the exciting ways the future of AI in prenatal care can be used. Artificial intelligence may be incorporated in wearable gadgets or in mobile apps, which will enable the continuous observation of fetal health and the early prevention of possible heart defects. This is because the systems would notify medical professionals and expectant parents about any anomalies and address them in time. In low-density or remote locations, AI-enhanced telemedicine systems may offer expert-level analysis without requiring people to visit in person, allowing people who otherwise would not receive prenatal care to do so.^{3,24,26}

Conclusion

Implementation of artificial intelligence in the process of detecting fetal congenital heart disease using fetal echocardiography and fetal MRI is changing the face of prenatal care. Although data availability issues, computational burdens, and clinical acceptability are still problematic, the possible advantages of AI are not in doubt, as better diagnostic accuracy, faster decision-making, and personalized care have been promoted. With more advances in AI technologies, they will transform the way we identify, diagnose, and treat congenital heart disease during the prenatal stage, resulting in improved quality of life for mothers and their babies.

Authors' Contribution

Conceptualization: Shamsi Ghaffari

Investigation: Shamsi Ghaffari

Writing—Original Draft Preparation: Shamsi Ghaffari

Writing—Review & Editing: Shamsi Ghaffari

Supervision: Shamsi Ghaffari

Competing Interests

The authors declare no competing interests.

Ethical Approval

Ethical approval was not required for this study because it is a review article based exclusively on previously published literature

Funding

This research received no external funding.

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