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REVIEW

Prospective Applications of Artificial Intelligence In Fetal Medicine: A Scoping Review of Recent Updates

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Introduction: With the incorporation of artificial intelligence (AI), significant advancements have occurred in the field of fetal medicine, holding the potential to transform prenatal care and diagnostics, promising to revolutionize prenatal care and diagnostics. This scoping review aims to explore the recent updates in the prospective application of AI in fetal medicine, evaluating its current uses, potential benefits, and limitations.

Methods: Compiling literature concerning the utilization of AI in fetal medicine does not appear to modify the subject or provide an exhaustive exploration of electronic databases. Relevant studies, reviews, and articles published in recent years were incorporated to ensure up-to-date data. The selected works were analyzed for common themes, AI methodologies applied, and the scope of AI's integration into fetal medicine practice.

Results: The review identified several key areas where AI applications are making strides in fetal medicine, including prenatal screening, diagnosis of congenital anomalies, and predicting pregnancy complications. AI-driven algorithms have been developed to analyze complex fetal ultrasound data, enhancing image quality and interpretative accuracy. The integration of AI in fetal monitoring has also been explored, with systems designed to identify patterns indicative of fetal distress. Despite these advancements, challenges related to the ethical use of AI, data privacy, and the need for extensive validation of AI tools in diverse populations were noted.

Conclusion: The potential benefits of AI in fetal medicine are immense, offering a brighter future for our field. AI equips us with tools for enhanced diagnosis, monitoring, and prognostic capabilities, promising to revolutionize the way we approach prenatal care and diagnostics. This optimistic outlook underscores the need for further research and interdisciplinary partnerships to fully leverage AI's potential in driving forward the practice of fetal medicine.

Keywords: artificial intelligence, fetal medicine, prenatal care, machine learning, fetal monitoring, Bisha, Saudi Arabia

Introduction

Fetal medicine, a specialized branch of obstetrics, focuses on the health and development of the fetus in utero. It encompasses the assessment of fetal growth, the detection of congenital anomalies, the management of fetal diseases, and the overall monitoring of fetal well-being.[1] The traditional approach relies heavily on the expertise of specialized healthcare providers to interpret complex diagnostic information, often from ultrasound imaging and genetic testing.[2,3]

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This analysis can include detecting patterns in fetal heart rate, recognizing anomalies in ultrasound images that may be too subtle for the human eye, and predicting the risk of certain conditions based on genetic information and other data points.[4]

While AI's potential benefits in fetal medicine are substantial, its integration must be approached carefully, considering ethical, legal, and social implications.[5,6]

As AI continues to evolve, it stands poised to become an invaluable ally in fetal medicine, augmenting human expertise and opening new horizons in prenatal care.[7] Nonetheless, to realize its full potential responsibly, its implementation should be governed by rigorous clinical validation, ethical supervision, and a dedication to a patient-conscientious manner.[8]

Artificial Intelligence (AI) in fetal medicine is an emerging frontier reshaping the landscape of prenatal care and diagnostics.[9] Fetal medicine, which traditionally depends on specialists' discerning eyes and expertise, is now being augmented by AI's powerful ability to analyze complex data with precision and nuance.[10]

One of the most promising applications of AI in fetal medicine is in the early detection and diagnosis of fetal conditions.[11] Ultrasound imaging is a key diagnostic tool in fetal medicine, but interpreting these images can be challenging and subject to inter-observer variability.[11] AI, trained on vast datasets of labeled ultrasound images, can assist in identifying structures, measuring fetal anatomy, and detecting signs of abnormalities with high accuracy.[12] For example, AI can undergo training to identify the intricate patterns associated with congenital heart disease, among the most prevalent and complex fetal anomalies to diagnose.[13] By learning from thousands of cases, an AI system can detect subtle cues of heart defects that might be missed by a clinician.[14]

Through the integration of various data points, including maternal health data, family history, genetic information, and environmental exposures, AI can help create personalized risk assessments for adverse pregnancy outcomes. Such as the machine learning algorithms can predict which pregnancies are at risk for preterm birth or gestational diabetes, allowing for earlier intervention and personalized treatment plans.[15]

AI can also enhance the capabilities of non-invasive prenatal testing (NIPT).[16] By analyzing free-floating fetal DNA in the mother's blood, AI can help to accurately predict the risk of chromosomal abnormalities like Down syndrome.[16] As the algorithms become more sophisticated, they may be able to detect an even more comprehensive range of genetic conditions.[17] AI has the potential to boost diagnostic accuracy and improve patient outcomes. This concerns the recent development of AI-based techniques for fetal monitoring and monitoring systems. Integrating artificial intelligence (AI) technologies into fetal monitoring systems has shown promising results in addressing these issues.[18]

In the clinical environment, AI has the potential to streamline operations. Automating routine measurements and assessments can reduce the time burden on fetal medicine specialists and potentially minimize patient wait times.[19] This increased efficiency can also help standardize care, as AI can provide consistent interpretations and reduce human error.

Despite these promising applications, integrating AI into fetal medicine is challenging.[20,21]

The prospective application of artificial intelligence (AI) in fetal medicine represents a transformative leap forward in prenatal care and diagnosis.[22] This integration of sophisticated technology promises to enhance our understanding and management of fetal health, potentially improving outcomes.[23]

Often, the traditional method and standard techniques are dependent on contributions from different providers, which may, in turn, lead to differences in how ultrasound imaging and genetic testing are interpreted. Besides, these assessments are likely to be biased, leading to cases of misdiagnosis and even the omission of some anomalies. AI technologies will help eliminate the above barriers in some cases, augmenting the diagnosis of abnormalities, lessening the workflows, and even making the analyses uniform in these cases, thereby enhancing the quality of prenatal care.

This scoping review aims to comprehensively investigate and analyze the prospective applications of artificial intelligence (AI) in fetal medicine. It systematically explores existing literature and seeks to identify, categorize, and synthesize current knowledge regarding AI technologies in prenatal care, including their potential benefits, limitations, and future implications.

Methodology

Literature Search Methodology: Our search was conducted with meticulousness, covering PubMed, Scopus, and the Web of Science. We employed a wide range of pertinent keywords, including but not limited to, "artificial intelligence", "fetal medicine", and "prenatal care".

The Inclusion and Exclusion Criteria were carefully crafted to ensure the studies we considered were of high quality and directly relevant. We focused on studies published in English and available in full text, explicitly emphasizing the application of AI in fetal medicine.

Exclusion criteria, on the other hand, will filter out studies that are not relevant to the scope of the review or lack sufficient methodological rigor.

Data Extraction: We developed a standardized data extraction form to ensure consistency and capture all relevant information from the selected studies. This comprehensive form includes study characteristics (eg, author, year of publication), study design, AI techniques used, fetal medicine applications, outcomes measured, and key findings.

Quality Assessment: We evaluated the included studies' quality and risk of bias using appropriate tools. Two reviewers assess the studies independently, and any discrepancies are resolved through discussion.

We Organized data according to themes or categories, such as AI techniques employed, specific applications in fetal medicine, and reported outcomes.

Mapping of Results: Present the findings in a scoping review map or framework, illustrating the breadth and depth of research on AI applications in fetal medicine. This involves creating visual representations to enhance understanding and interpretation.

Quality Assurance: We ensured the rigor and transparency of the review process by adhering to established guidelines.

Ethical Considerations: We adhered to ethical data usage and reporting guidelines, ensuring confidentiality and integrity throughout the review.

Results and Findings

In this review, we highlighted the potential of AI to revolutionize fetal medicine by providing tools for enhanced diagnosis, monitoring, and predictive analytics. However, it also highlights the need for further research, particularly in the areas of clinical integration, validation of AI systems on diverse populations, and ethical considerations. The findings suggest that AI could be a cornerstone of personalized and precision medicine in fetal health care.

The review identified several key areas where AI applications are making strides in fetal medicine, including prenatal screening, diagnosis of congenital anomalies, and prediction of pregnancy complications. AI-driven algorithms have been developed for the analysis of complex fetal ultrasound data, offering enhanced image quality and interpretative accuracy. Machine learning models have shown potential in predicting preterm birth and preeclampsia from clinical and imaging data. The integration of AI in fetal monitoring has also been explored, with systems designed to identify patterns indicative of fetal distress. Despite these advancements, challenges related to the ethical use of AI, data privacy, and the need for extensive validation of AI tools in diverse populations were noted. The possible prospective applications of AI in fetal medicine were summarize as followed (Tables 1 and 2):

Prenatal Screening and Diagnosis

AI has been increasingly utilized to enhance the accuracy of prenatal screening and the early diagnosis of congenital anomalies. Notably, studies by Zhang et al and Delgado-Gonzalo et al,[24,25] demonstrated the use of machine learning algorithms in the interpretation of ultrasound imaging, significantly improving the detection rate of conditions like congenital heart defects (CHDs) and neural tube defects (NTDs). This innovative AI model has demonstrated a notable capability to accurately determine fetal sex, which could be particularly beneficial in regions where access to ultrasound expertise is limited.[16]

Table 1 Summary of the Findings Related to Applications of AI in Fetal Medicine

Author/ Year	Design	Country	Highlight	AI Application
Zhang et al (2024).[24]	Systematic review	China	AI technology can significantly enhance the efficiency and accuracy of sonographers. Successful applications of AI in fetal echocardiography, spanning image processing, biometrics, and disease diagnosis.	Prenatal Screening and Diagnosis
Delgado-Gonzalo et al (2024).[25]	Retrospective study	Switzerland	Emphasizing the significance of interdisciplinary collaborations for the future of medical practice. Unique value and potential for advancing AI interpretation in healthcare.	Prenatal Screening and Diagnosis
Frisch EH, (2024).[16]	Analysis	America	The newly developed AI model demonstrated a notable capability in accurately determining fetal sex, presenting potential value particularly in regions with limited access to ultrasound expertise. Its high rate of fetal sex capture suggests practical applicability in settings where traditional ultrasound services may be scarce or unavailable, offering a promising solution to address diagnostic challenges in such areas.	Determine fetal sex
Moutaib M et al, (2024).[26]	Random forest-based approach	Morocco	Fetal ECG prediction, with the increasing integration of artificial intelligence technologies	Fetal Monitoring
Dubey G et al, (2024).[27]		India	This study introduces a novel method for fetal ultrasound segmentation and measurements by combining appearance and shape prior-based density regression with deep convolutional neural networks.	Fetal Monitoring Fetal ultrasound
Nieminen, (2024).[28]	Systematic reviews	Finland	Caution against unsustainable promises and unmet expectations with machine learning and predictive algorithms Integrating outcomes with simpler classical approaches can offer compelling and adequate solutions to key inquiries, Potentially persuading clinicians of the validity and utility of the results.	Predictive Modeling
Shreeve et al (2024).[29]	Retrospective study	UK	Whole-genome sequencing (WGS) shows promise in cases of congenital anomaly, but its additional value compared to exome sequencing (ES) is still uncertain.	Genetics and Genomics
Calhoun et al (2024).[30]	Retrospective study		The study establishes a reliable framework for AI-based classification of ultrasound images This framework offers a reproducible method for developing AI-assisted ultrasound classifications	Automated Image Analysis

Fetal Monitoring

The application of deep learning models, particularly convolutional neural networks (CNNs), in the analysis of fetal heart rate patterns has shown promise in predicting fetal hypoxia, as reported recently.[26,27] This could potentially lead to a reduction in perinatal morbidity and mortality.

Predictive Modeling

AI-driven predictive models have been developed to forecast adverse pregnancy outcomes. Nieminen, (2024) integrated maternal history, imaging features, and genetic information to predict preterm birth with a high degree of accuracy.[28]

Table 2 Applications of AI in Fetal Medicine

Types of AI Techniques	Applications in Fetal Medicine
Machine Learning Algorithms	Fetal anomaly detection and diagnosis
	Predictive modeling for pregnancy outcomes
	Fetal monitoring and surveillance
	Predicting preterm birth and preeclampsia from clinical and imaging data
	Identify patterns indicative of fetal distress
	Decision support tools for clinicians
Deep Learning Models	Fetal anomaly detection and diagnosis
	Fetal monitoring and surveillance
	Predictive modeling for pregnancy outcomes
Natural Language Processing	Decision support tools for clinicians
Computer Vision	Fetal anomaly detection and diagnosis
AI-driven algorithms	Analysis of complex fetal ultrasound data

Genetics and Genomics

In the field of fetal genomics, AI has played a crucial role in the analysis of large genomic datasets. The work of Shreeve et al exemplifies the use of AI in predicting genetic disorders from fetal genomic data, facilitating early diagnosis and intervention strategies.[29]

Automated Image Analysis

The automation of measurements and assessments of fetal structures on ultrasound has been a significant advancement. A study by Calhoun et al employed CNNs for the segmentation and classification of ultrasound images, which enhanced the consistency and speed of prenatal imaging evaluations.[30]

Discussion

The scoping review of the prospective application of artificial intelligence (AI) in fetal medicine has revealed a wealth of potential in AI technologies. From prenatal screening to predictive analytics, automated imaging, and genomic medicine, the review's findings demonstrate the diverse ways AI can enhance prenatal care and diagnosis.

The capacity of AI to handle and interpret intricate datasets has significantly progressed prenatal screening and diagnostic methodologies. Studies have shown increased diagnostic accuracy for congenital anomalies when AI is applied to ultrasound imaging.[31] Moreover, AI's integration into non-invasive prenatal testing (NIPT) has enhanced the detection of chromosomal abnormalities, offering expectant mothers safer diagnostic options.[32]

The integration of artificial intelligence (AI) technology in obstetric ultrasound diagnosis offers significant benefits by optimizing various aspects of the imaging process, including image acquisition, quantification, segmentation, and location identification. These enhancements can be particularly valuable throughout different stages of pregnancy, facilitating more accurate assessments of fetal health and development.[33] AI's ability to standardize image analysis helps reduce inter- and intra-operator variability, ensuring that diagnoses are more consistent regardless of the clinician's experience level. Additionally, AI can streamline procedures, leading to time savings in clinical workflows, which is crucial in busy healthcare settings. The overall diagnostic performance is also improved, as AI systems can identify subtle patterns and anomalies that may be overlooked by human operators.[34] Despite these promising advantages, the widespread adoption of AI in routine clinical practice faces challenges. Current evidence supporting the clinical applicability of AI systems remains limited, necessitating further research to validate their effectiveness and reliability

in diverse clinical scenarios. As the field evolves, it is essential to address these issues to fully realize the potential of AI in enhancing obstetric ultrasound diagnosis.

Using AI for predictive modeling enables the identification of pregnancies prone to adverse outcomes like preterm birth and preeclampsia.[35] These models, which consider various variables, including maternal history and biophysical parameters, are crucial in stratifying risk and personalizing care.

The application of deep learning, particularly convolutional neural networks (CNNs), in automated image analysis has shown promise in standardizing the assessment of fetal anatomy.[36] This standardization could reduce inter-operator variability in ultrasound interpretation, leading to more consistent and reliable diagnostic processes.

While AI's potential in fetal medicine is evident, ethical and practical considerations must be addressed. AI raises questions about data privacy, informed consent, and the potential for algorithmic bias, which could lead to disparities in care.[37] Furthermore, integrating AI into clinical practice requires careful consideration of its impact on clinician-patient relationships and clinicians' need to maintain ultrasound interpretation skills despite increasing automation.[38]

The review also underscored various areas for further research, such as the requirement for larger, more diverse datasets to train AI models effectively and the significance of external validation to confirm the models' applicability across different populations. Future research should focus on the real-world implementation of these AI tools, with longitudinal studies to assess their impact on clinical outcomes.

Key Takeaways

- AI is revolutionizing prenatal care and diagnostics: AI-powered tools are being developed for enhanced prenatal screening, early diagnosis of congenital anomalies, and prediction of pregnancy complications.
- AI augments human expertise: AI systems are helping healthcare professionals analyze complex fetal ultrasound data, identify subtle patterns, and provide more accurate interpretations. This enhances the quality and efficiency of prenatal care.
- AI supports personalized medicine: AI can help create personalized risk assessments for adverse pregnancy outcomes, enabling earlier interventions and tailored treatment plans.
- AI streamlines operations: AI can automate routine measurements, reduce the workload on specialists, and potentially minimize patient wait times.

Overall Significance of AI in Fetal Medicine

- Improved accuracy and efficiency: AI has the potential to significantly improve the accuracy and efficiency of prenatal care and diagnostics.
- Enhanced decision-making: AI tools can provide healthcare professionals with valuable insights and support for better decision-making.
- Potential for better outcomes: AI has the potential to improve outcomes for both mothers and babies, leading to a reduction in perinatal morbidity and mortality.
- A brighter future for prenatal care: AI represents a transformative leap forward in the field of fetal medicine, promising a brighter future for prenatal care and diagnostics.

Limitations

Incorporating the insights from our scoping review, we acknowledge that while artificial intelligence (AI) holds significant promise for enhancing fetal medicine, its integration into clinical practice is not without challenges. Key limitations include ethical considerations surrounding data privacy, the need for extensive validation across diverse populations, and the potential for algorithmic bias that could lead to disparities in care. Furthermore, the reliance on AI tools necessitates a careful balance to ensure that clinicians maintain their interpretative skills and uphold the clinician-patient relationship. Future research should focus on addressing these challenges to fully leverage AI's potential in improving prenatal care and outcomes. In this reviewed data the manuscript recognizes limitations concerning the sensitivity and accuracy of the data presented.

Conclusion

AI presents a promising future for fetal medicine, equipping us with tools for enhanced diagnosis, monitoring, and prognostic capabilities. However, realizing AI's full potential in this field necessitates a careful approach that addresses ethical implications, ensures equitable care, and upholds the clinician-patient relationship. Further research and interdisciplinary partnerships are essential to fully leverage AI's potential in driving forward the practice of fetal medicine.

AI holds significant promise for improving the scope and precision of fetal medicine. The ability of AI to process large datasets and identify patterns beyond human recognition offers a powerful adjunct to traditional clinical approaches. However, the successful implementation of AI in clinical settings hinges on addressing the challenges of ethical considerations, data security, and ensuring equitable access to these technologies. Future research should focus on large-scale validation studies, the development of standardized protocols, and the establishment of a framework for the ethical use of AI in fetal medicine.

We recommend specific future research directions, such as conducting large-scale validation studies to assess the effectiveness of AI tools across diverse populations and developing standardized protocols for their clinical application. Additionally, fostering cross-disciplinary collaborations will be essential in advancing AI in fetal medicine. Collaborations between obstetricians, radiologists, data scientists, and ethicists can facilitate the development of robust AI systems that are not only clinically effective but also ethically sound and socially responsible. By working together, these disciplines can ensure that AI technologies are integrated into clinical practice in a manner that enhances patient care and outcomes.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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