

A New Frontier in Prenatal Care: Exploring the Impact of Artificial Intelligence on Perinatology

ARTICLE INFO

Article Type

Review Article

Authors

AboTaleb Saremi^{1,2}, Bahareh Abbasi^{3*}, Elham Karimi-MansoorAbad^{1,2}, Yasin Ashourian^{1,2}

1- Sarem Gynecology, Obstetrics and Infertility Research Center, Sarem Women's Hospital, Iran University of Medical Science (IUMS), Tehran, Iran.
2- Sarem Cell Research Center (SCRC), Sarem Women's Hospital, Tehran, Iran.
3- Department of Medical Genetics, National Institute of Genetic Engineering and Biotechnology (NIGEB), Tehran, Iran.

*Corresponding Authors:

Bahareh Abbasi¹; MD, Department of Medical Genetics, National Institute of Genetic Engineering and Biotechnology (NIGEB), Tehran, Iran.
Email: b.abbasi@nigeb.ac.ir

ABSTRACT

The paper discusses the significant impact of Artificial Intelligence (AI) on perinatology, highlighting how it has revolutionized maternal and fetal healthcare. AI's role in perinatology is multifaceted, enhancing fetal and maternal health monitoring through advanced algorithms in ultrasound imaging and predictive analytics. It has improved the detection and management of conditions like preterm births and preeclampsia, offering more personalized care. The paper also addresses the ethical and legal considerations of AI in healthcare, emphasizing the importance of privacy, security, and ethical decision-making. Looking ahead, the paper envisions a future where AI's integration with genomic medicine and remote monitoring technologies will further advance perinatal care, making it more accessible and efficient. However, it underscores the necessity of responsible and equitable use of AI, ensuring it benefits all segments of society. The conclusion reiterates the transformative potential of AI in enhancing perinatal care, balancing technological innovation with ethical, equitable healthcare practices.

Keywords: Artificial Intelligence in Perinatology, Fetal Health Monitoring, Maternal Health Management, Predictive Analytics in Pregnancy, Ethical Considerations in AI Healthcare.

Received: 11 November 2023
Accepted: 11 December, 2023
e Published: 3 August 2024

Article History

Copyright© 2021, ASP Ins. This open-access article is published under the terms of the Creative Commons Attribution-Noncommercial 4.0 International License which permits Share (copy and distribute the material in any medium or format) and Adapt (remix, transform, and build upon the material) under the Attribution-Noncommercial terms

Introduction

The realm of perinatology, which focuses on the care of the fetus and mother around the time of birth, has always been field rich in complexity and nuance. Its critical nature, dealing with two lives simultaneously, demands precision, foresight, and a deep understanding of the myriad factors that influence both maternal and fetal health. The advent and rapid evolution of artificial intelligence (AI) in medicine presents a revolutionary opportunity to enhance and redefine perinatal care.

AI, with its remarkable ability to analyze large datasets, learn from patterns, and make predictions, is increasingly being integrated into the healthcare sector, including perinatology. This integration promises to offer unprecedented insights into fetal development, improve maternal health outcomes, and even predict and manage potential complications before they become critical issues. The use of machine learning algorithms, deep learning frameworks, and predictive analytics in interpreting complex medical data has started to transform the landscape of perinatal care, making interventions more timely, personalized, and effective [1-4].

Moreover, AI's role in medical imaging, particularly in ultrasound technology, has begun to augment the capabilities of perinatologists in diagnosing and monitoring fetal health. These advancements not only improve the accuracy of diagnoses but also contribute to the development of new protocols and treatment plans tailored to individual patient needs [5, 6].

As we step into this new era, where technology and medicine intertwine more closely than ever, it is imperative to examine the multifaceted impact of AI on perinatology. This narrative review aims to explore the ways in which AI is reshaping perinatal care, from enhancing fetal and maternal health monitoring to addressing complex ethical and legal considerations. By delving into current applications, successes, challenges, and future potential, we seek to provide a comprehensive understanding of how AI is revolutionizing the field of perinatology, paving the way for an era of more informed, efficient, and compassionate care [7, 8].

AI Technologies in Perinatology

AI technologies have significantly impacted the field of perinatology, offering innovative approaches to maternal and fetal health management. The integration of machine learning and predictive analytics has been a game-changer. These technologies enable healthcare professionals to analyze vast amounts of data, including patient history, genetic information, and real-time monitoring data, to make more accurate

predictions about pregnancy outcomes. For instance, AI-driven models can now forecast the risk of preterm birth or identify potential complications much earlier than traditional methods [9, 10].

Neural networks and deep learning, subsets of AI, have further enhanced perinatal care. In fetal health monitoring, one of the most striking applications is in the field of ultrasound imaging. AI algorithms can interpret ultrasound results with remarkable precision, assisting in detecting anomalies and assessing fetal growth patterns more accurately than ever before. This capability is crucial for early intervention in cases where fetal distress or developmental issues are suspected [11-13].

AI's impact extends to maternal health as well. It plays a vital role in predicting and managing preterm births, one of the leading causes of neonatal mortality. By analyzing patterns in maternal health data, AI systems can alert healthcare providers to early signs of labor, enabling timely and appropriate interventions. Additionally, in conditions like preeclampsia, a serious pregnancy complication characterized by high blood pressure and signs of damage to other organ systems, AI tools help in early detection and monitoring, greatly improving maternal and fetal outcomes [14-16].

The use of AI in perinatology also brings with it ethical and legal considerations. Issues surrounding data privacy and security are paramount, as sensitive health information is at stake. Furthermore, the ethical implications of AI decision-making in healthcare, especially in scenarios involving high-risk pregnancies, necessitate careful consideration. It's essential to strike a balance between leveraging AI's capabilities and maintaining human oversight in clinical decision-making processes [17, 18].

Despite these challenges, the future of AI in perinatology looks promising. The ongoing advancements in AI are expected to deepen our understanding of perinatal health, leading to more personalized and effective care strategies. As AI continues to evolve, it will undoubtedly open up new avenues for innovation and improvement in perinatal care, enhancing both maternal and fetal outcomes [19, 20].

AI in Fetal Health Monitoring

AI in Fetal Health Monitoring has emerged as a transformative force in perinatology, offering unprecedented opportunities for enhancing prenatal care and fetal health outcomes. The integration of AI technologies in fetal monitoring primarily revolves around the application of advanced algorithms in ultrasound imaging and the prediction of fetal distress

and outcomes. In the realm of ultrasound imaging, AI has revolutionized the way fetal images are captured, interpreted, and utilized for clinical decision-making. Machine learning models, trained on vast datasets of ultrasound images, can now assist in identifying fetal anomalies and growth patterns with a level of precision that was previously unattainable. This has significantly improved the ability of perinatologists to detect and manage conditions like congenital heart defects, neural tube defects, and chromosomal anomalies at an early stage ^[21, 22].

Furthermore, the predictive capabilities of AI extend beyond image interpretation. By analyzing patterns in fetal heart rate, movements, and other physiological parameters, AI systems can identify signs of fetal distress more accurately and promptly than traditional methods. This is particularly crucial in managing high-risk pregnancies, where early detection of potential issues can lead to timely interventions and better outcomes ^[23, 24].

AI's role in predicting fetal outcomes is another area of significant advancement. Algorithms that incorporate a wide range of data, including maternal health records, environmental factors, and genetic information, are being developed to forecast risks such as preterm birth, low birth weight, and other complications. These predictive models offer a more personalized approach to perinatal care, enabling healthcare providers to tailor their strategies according to the specific risks and needs of each pregnancy ^[25-27].

The integration of AI in fetal health monitoring not only enhances the accuracy and efficiency of prenatal care but also opens new avenues for research in perinatology. By leveraging the vast amount of data generated during pregnancy, AI can help unravel complex biological processes and contribute to our understanding of fetal development and maternal-fetal interactions ^[28-30].

However, the adoption of AI in fetal health monitoring is not without challenges. Issues related to the standardization of data, ethical considerations, and ensuring the accuracy and reliability of AI systems remain areas of ongoing research and development. Overall, AI's impact on fetal health monitoring marks a significant leap forward in perinatology. It enhances the ability of healthcare professionals to monitor and manage fetal health, offering promising prospects for improved maternal and fetal outcomes. As AI technology continues to evolve, it is poised to play an increasingly vital role in shaping the future of prenatal care ^[31-33].

AI in Maternal Health

AI in maternal health represents a significant leap forward in how we understand, monitor, and intervene in various aspects of maternal care. This advancement

is particularly evident in the management and prediction of complications that can arise during pregnancy. One of the most critical applications of AI in maternal health is in the prediction and management of preterm births, which are a leading cause of neonatal mortality worldwide. Machine learning models are being developed to analyze patterns in historical patient data, identifying risk factors that contribute to premature labor. These models can predict with a higher degree of accuracy which pregnancies are at risk, enabling early intervention and more tailored prenatal care ^[34-36].

Another area where AI is making strides is in the detection and management of preeclampsia, a condition characterized by high blood pressure and often protein in the urine, which can lead to severe complications for both mother and baby if not managed appropriately. AI algorithms are capable of sifting through large datasets, detecting subtle changes in a mother's vitals that might indicate the onset of preeclampsia. This early detection is crucial, as it allows for prompt treatment, potentially reducing the risk of severe complications ^[37, 38].

AI is also being integrated into routine prenatal care through the development of smart wearable devices and apps. These tools can continuously monitor vital health parameters such as blood pressure, heart rate, and blood glucose levels, providing real-time data that can be analyzed by AI systems. This constant monitoring ensures that any deviations from the norm can be flagged immediately, facilitating timely medical interventions ^[39-41].

Moreover, AI is revolutionizing ultrasound imaging, providing clearer and more detailed images, and enabling the detection of potential issues much earlier in the pregnancy. Advanced image recognition software can assist in identifying fetal abnormalities that might have been missed by the human eye, enhancing the quality of prenatal diagnostics ^[42-44].

The integration of AI in maternal health is not without its challenges. Concerns regarding data privacy, the need for large and diverse datasets to train AI models effectively, and the potential for algorithmic bias all need to be addressed. However, the potential benefits, including reduced maternal and fetal morbidity and mortality, improved patient outcomes, and more personalized care, are immense. As technology continues to evolve, AI is set to play an increasingly central role in transforming maternal healthcare, offering a more proactive, predictive, and personalized approach to maternal wellness and care ^[45-47].

Real-World Applications

The integration of Artificial Intelligence (AI) into the field of perinatology has led to significant advancements and real-world applications that are reshaping maternal and fetal healthcare. In recent

years, AI has emerged as a powerful tool for enhancing the diagnosis, monitoring, and management of various perinatal conditions, offering more personalized and accurate care for both mothers and their unborn children ^[48-50].

One of the most notable applications of AI in perinatology is in fetal health monitoring. AI algorithms, particularly those based on machine learning and neural networks, have been increasingly used to interpret fetal ultrasound images. These algorithms can detect anomalies that might be missed by the human eye, predict fetal distress, and assess the growth and development of the fetus more accurately. This has been particularly useful in high-risk pregnancies, where early detection of potential issues is crucial ^[51-53].

AI is also revolutionizing the way maternal health is monitored and managed. For instance, AI systems are being employed to predict the risk of preterm births, which remains a leading cause of neonatal mortality worldwide. By analyzing large datasets that include medical history, genetic information, and lifestyle factors, AI models can identify women at high risk of early labor, allowing for timely interventions ^[54-56].

Another significant area is the management of preeclampsia, a dangerous pregnancy complication characterized by high blood pressure. AI tools can help in early detection by continuously analyzing the mother's vital signs and other health indicators, facilitating prompt treatment to prevent severe complications. The real-world impact of AI in perinatology extends beyond these clinical applications. Ethical and legal considerations are also at the forefront, particularly regarding data privacy and the use of AI in decision-making processes. As AI systems handle sensitive health data, ensuring the security and confidentiality of this information is paramount. Additionally, the ethical implications of AI decision-making in perinatology, such as the extent to which these systems should influence treatment choices, are subjects of ongoing debate ^[57, 58].

Despite the challenges, the future of AI in perinatology holds promising prospects. As AI technology continues to evolve, it is anticipated that its integration into perinatal care will become more seamless and widely adopted, offering innovative solutions for early detection and management of perinatal conditions, ultimately leading to improved outcomes for mothers and their babies. The field is on the cusp of a new era where AI not only augments clinical decision-making but also paves the way for groundbreaking research and novel therapeutic approaches in maternal-fetal medicine ^[59-61].

Future Directions and Innovations

The future of AI in perinatology promises to be both innovative and transformative, reshaping the way

perinatal care is delivered and experienced. As we look ahead, several emerging trends and potential developments stand out, signaling an exciting era of technological advancement in this vital field of medicine ^[62-64].

One of the most significant future directions is the integration of AI with genomic medicine in perinatal care. This convergence has the potential to revolutionize prenatal diagnostics and treatments. By leveraging AI algorithms to analyze genetic data, healthcare professionals could gain unprecedented insights into fetal health much earlier in the pregnancy. This would not only help in identifying genetic disorders but also in tailoring personalized care plans for both the mother and the fetus ^[65-67].

Another area ripe for innovation is the enhancement of remote monitoring technologies. With the advent of wearable devices and smart sensors, continuous monitoring of fetal and maternal health parameters could become more feasible and accurate. AI can play a crucial role in analyzing the vast amounts of data generated by these devices, providing real-time alerts and insights to healthcare providers. This would be especially beneficial in managing high-risk pregnancies, where constant vigilance is paramount ^[68, 69].

Moreover, AI-driven predictive models are set to become more sophisticated. As machine learning algorithms become more advanced and trained on larger, more diverse datasets, their ability to predict complications like preterm births, preeclampsia, and fetal distress will improve. This predictive prowess will aid in early interventions, potentially reducing the rates of maternal and neonatal morbidity and mortality. The development of AI-powered telemedicine platforms is also on the horizon. These platforms could facilitate better access to perinatal care, especially in underserved or remote areas. By enabling expectant mothers to consult with specialists virtually, geographical and logistical barriers could be significantly reduced. Additionally, these platforms can be equipped with AI tools to assist in preliminary diagnostics and triaging, ensuring timely and appropriate care ^[70-72].

In parallel, we are likely to witness the rise of AI in educational and training tools for perinatal healthcare professionals. Through virtual simulations and AI-driven scenarios, practitioners can hone their skills and stay updated with the latest advancements in perinatal care. This approach to education could greatly enhance the quality of care, preparing professionals for a wide range of clinical situations with greater confidence and competence ^[73-75].

However, alongside these technological advancements, there will be an increasing need to address ethical, legal, and social implications. Issues around data privacy, consent, and the transparency of

AI algorithms will require careful consideration and robust governance frameworks. Ensuring that these technologies are accessible and beneficial to all segments of society, regardless of socioeconomic status, will be crucial in avoiding disparities in healthcare outcomes [76-78].

The future of AI in perinatology is not just about technological innovation but also about its responsible and equitable integration into healthcare systems. With the right balance of technology, ethics, and accessibility, AI has the potential to bring about a new era in perinatal care, marked by enhanced safety, efficiency, and personalized care experiences for mothers and babies alike. The journey towards this future is as much about developing advanced AI solutions as it is about shaping the context in which these solutions are implemented. By focusing on collaborative efforts that bring together technologists, healthcare professionals, ethicists, and policymakers, we can ensure that the advancements in AI not only push the boundaries of what is possible in perinatology but also align with the broader goals of equitable and ethical healthcare [79-81].

In conclusion, the integration of AI in perinatology holds immense promise for the betterment of maternal and fetal health. As we navigate the complexities and possibilities of this integration, the focus should always remain on enhancing the quality of care while safeguarding the principles of equity, ethics, and human-centeredness in healthcare. This approach will not only lead to technological breakthroughs but also ensure that these breakthroughs translate into meaningful improvements in the lives of mothers and their babies [79-81].

Conclusion

In conclusion, the integration of Artificial Intelligence (AI) into perinatology heralds a transformative era in maternal and fetal healthcare. AI's advanced capabilities in data analysis, predictive modeling, and machine learning are revolutionizing prenatal diagnostics, fetal health monitoring, and maternal care. Its application ranges from enhancing the accuracy of ultrasound imaging and predicting fetal distress to managing complex conditions like preterm births and preeclampsia. These technological advancements are not only improving the accuracy and efficiency of perinatal care but also opening new avenues for research and personalized treatment strategies.

Conflict of Interests

There was no conflict of interest in this study.

Source of Funding

This study has been financially supported by Sarem Gynecology, Obstetrics and Infertility Research Center, Sarem Women's Hospital

Author's ORCID

AboTaleb Saremi

<http://orcid.org/0000-0003-4191-6624>

Reference:

1. Ye Z, Xuan R, Ouyang M, Wang Y, Xu J, Jin W. Prediction of placenta accreta spectrum by combining deep learning and radiomics using T2WI: a multicenter study. *Abdom Radiol (NY)*. 2022;47(12):4205-18.
2. Torrents-Barrena J, Monill N, Piella G, Gratacós E, Eixarch E, Ceresa M, González Ballester MA. Assessment of Radiomics and Deep Learning for the Segmentation of Fetal and Maternal Anatomy in Magnetic Resonance Imaging and Ultrasound. *Acad Radiol*. 2021;28(2):173-88.
3. de Vries IR, van Laar J, van der Hout-van der Jagt MB, Clur SB, Vullings R. Fetal electrocardiography and artificial intelligence for prenatal detection of congenital heart disease. *Acta Obstet Gynecol Scand*. 2023;102(11):1511-20.
4. Story L, Zhang T, Uus A, Hutter J, Egloff A, Gibbons D, et al. Antenatal thymus volumes in fetuses that delivered <32 weeks' gestation: An MRI pilot study. *Acta Obstet Gynecol Scand*. 2021;100(6):1040-50.
5. Tanos V, Laidlaw J, Tanos P, Papadopoulou A. New insights into the neural network of the nongravid uterus. *Adv Clin Exp Med*. 2022;31(10):1153-62.
6. Rodriguez CI, Vergara VM, Davies S, Calhoun VD, Savage DD, Hamilton DA. Detection of prenatal alcohol exposure using machine learning classification of resting-state functional network connectivity data. *Alcohol*. 2021;93:25-34.
7. Marwaha A, Chitayat D, Meyn MS, Mendoza-Londono R, Chad L. The point-of-care use of a facial phenotyping tool in the genetics clinic: Enhancing diagnosis and education with machine learning. *Am J Med Genet A*. 2021;185(4):1151-8.

8. Bahado-Singh R, Friedman P, Talbot C, Aydas B, Southekal S, Mishra NK, et al. Cell-free DNA in maternal blood and artificial intelligence: accurate prenatal detection of fetal congenital heart defects. *Am J Obstet Gynecol*. 2023;228(1):76.e1-e10.
9. Cersonsky TEK, Ayala NK, Pinar H, Dudley DJ, Saade GR, Silver RM, Lewkowitz AK. Identifying risk of stillbirth using machine learning. *Am J Obstet Gynecol*. 2023;229(3):327.e1-e16.
10. Khalil A, Bellesia G, Norton ME, Jacobsson B, Haeri S, Egbert M, et al. The Role of cfDNA Biomarkers and Patient Data in the Early Prediction of Preeclampsia: Artificial Intelligence Model. *Am J Obstet Gynecol*. 2024.
11. Burgos-Artizzu XP, Coronado-Gutiérrez D, Valenzuela-Alcaraz B, Vellvé K, Eixarch E, Crispí F, et al. Analysis of maturation features in fetal brain ultrasound via artificial intelligence for the estimation of gestational age. *Am J Obstet Gynecol MFM*. 2021;3(6):100462.
12. Lee SJ, Garcia GP, Stanhope KK, Platner MH, Boulet SL. Interpretable machine learning to predict adverse perinatal outcomes: examining marginal predictive value of risk factors during pregnancy. *Am J Obstet Gynecol MFM*. 2023;5(10):101096.
13. Sarno L, Neola D, Carbone L, Saccone G, Carlea A, Miceli M, et al. Use of artificial intelligence in obstetrics: not quite ready for prime time. *Am J Obstet Gynecol MFM*. 2023;5(2):100792.
14. Suhag A, Kidd J, McGath M, Rajesh R, Gelfinbein J, Cacace N, et al. ChatGPT: a pioneering approach to complex prenatal differential diagnosis. *Am J Obstet Gynecol MFM*. 2023;5(8):101029.
15. Fang T, Yuan P, Gong C, Jiang Y, Yu Y, Shang W, et al. Fast label-free recognition of NRBCs by deep-learning visual object detection and single-cell Raman spectroscopy. *Analyst*. 2022;147(9):1961-7.
16. Cao R, Huang Y, Rahmani AM, Lindsay K. Prenatal Cortisol Levels Estimation Using Heart Rate and Heart Rate Variability: A Weak Supervised Learning Based Approach. *Annu Int Conf IEEE Eng Med Biol Soc*. 2022;2022:4430-3.
17. Gabler E, Nissen M, Altstidl TR, Titzmann A, Packhauser K, Maier A, et al. Fetal Re-Identification in Multiple Pregnancy Ultrasound Images Using Deep Learning. *Annu Int Conf IEEE Eng Med Biol Soc*. 2023;2023:1-4.
18. Preis H, Djurić PM, Ajirak M, Chen T, Mane V, Garry DJ, et al. Applying machine learning methods to psychosocial screening data to improve identification of prenatal depression: Implications for clinical practice and research. *Arch Womens Ment Health*. 2022;25(5):965-73.
19. Dan T, Chen X, He M, Guo H, He X, Chen J, et al. DeepGA for automatically estimating fetal gestational age through ultrasound imaging. *Artif Intell Med*. 2023;135:102453.
20. Sun Y, Yang H, Zhou J, Wang Y. ISSMF: Integrated semantic and spatial information of multi-level features for automatic segmentation in prenatal ultrasound images. *Artif Intell Med*. 2022;125:102254.
21. Betts KS, Chai K, Kisely S, Alati R. Development and validation of a machine learning-based tool to predict autism among children. *Autism Res*. 2023;16(5):941-52.
22. Mundorf A, Kubitz N, Hüntel K, Matsui H, Juckel G, Ocklenburg S, Freund N. Maternal immune activation leads to atypical turning asymmetry and reduced DRD2 mRNA expression in a rat model of schizophrenia. *Behav Brain Res*. 2021;414:113504.
23. Sreelakshmy R, Titus A, Sasirekha N, Logashanmugam E, Begam RB, Ramkumar G, Raju R. An Automated Deep Learning Model for the Cerebellum Segmentation from Fetal Brain Images. *Biomed Res Int*. 2022;2022:8342767.
24. Tang J, Han J, Xue J, Zhen L, Yang X, Pan M, et al. A Deep-Learning-Based Method Can Detect Both Common and Rare Genetic Disorders in Fetal Ultrasound. *Biomedicine*. 2023;11(6).
25. Ball G, Oldham S, Kyriakopoulou V, Williams LZJ, Karolis V, Price A, et al. Molecular signatures of cortical expansion in the human fetal brain. *bioRxiv*. 2024.
26. Newton SM, Distler S, Woodworth KR, Chang D, Roth NM, Board A, et al. Leveraging automated approaches to categorize birth defects from abstracted birth hospitalization data. *Birth Defects Res*. 2024;116(1):e2267.

27. Lei WL, Du Z, Meng TG, Su R, Li YY, Liu W, et al. SRSF2 is required for mRNA splicing during spermatogenesis. *BMC Biol.* 2023;21(1):231.
28. Abraham A, Le B, Kosti I, Straub P, Velez-Edwards DR, Davis LK, et al. Dense phenotyping from electronic health records enables machine learning-based prediction of preterm birth. *BMC Med.* 2022;20(1):333.
29. Dejene BE, Abuhay TM, Bogale DS. Predicting the level of anemia among Ethiopian pregnant women using homogeneous ensemble machine learning algorithm. *BMC Med Inform Decis Mak.* 2022;22(1):247.
30. Feng J, Liang J, Qiang Z, Hao Y, Li X, Li L, et al. A hybrid stacked ensemble and Kernel SHAP-based model for intelligent cardiotocography classification and interpretability. *BMC Med Inform Decis Mak.* 2023;23(1):273.
31. Ma JH, Feng Z, Wu JY, Zhang Y, Di W. Learning from imbalanced fetal outcomes of systemic lupus erythematosus in artificial neural networks. *BMC Med Inform Decis Mak.* 2021;21(1):127.
32. Darsareh F, Ranjbar A, Farashah MV, Mehrnough V, Shekari M, Jahromi MS. Application of machine learning to identify risk factors of birth asphyxia. *BMC Pregnancy Childbirth.* 2023;23(1):156.
33. Han X, Yu J, Yang X, Chen C, Zhou H, Qiu C, et al. Artificial intelligence assistance for fetal development: evaluation of an automated software for biometry measurements in the mid-trimester. *BMC Pregnancy Childbirth.* 2024;24(1):158.
34. Ji C, Liu K, Yang X, Cao Y, Cao X, Pan Q, et al. A novel artificial intelligence model for fetal facial profile marker measurement during the first trimester. *BMC Pregnancy Childbirth.* 2023;23(1):718.
35. Jing G, Huwei S, Chao C, Lei C, Ping W, Zhongzhou X, et al. A predictive model of macrosomic birth based upon real-world clinical data from pregnant women. *BMC Pregnancy Childbirth.* 2022;22(1):651.
36. Khatibi T, Hanifi E, Sepehri MM, Allahqoli L. Proposing a machine-learning based method to predict stillbirth before and during delivery and ranking the features: nationwide retrospective cross-sectional study. *BMC Pregnancy Childbirth.* 2021;21(1):202.
37. Lee KS, Kim HY, Lee SJ, Kwon SO, Na S, Hwang HS, et al. Prediction of newborn's body mass index using nationwide multicenter ultrasound data: a machine-learning study. *BMC Pregnancy Childbirth.* 2021;21(1):172.
38. Ranjbar A, Montazeri F, Ghamsari SR, Mehrnough V, Roozbeh N, Darsareh F. Machine learning models for predicting preeclampsia: a systematic review. *BMC Pregnancy Childbirth.* 2024;24(1):6.
39. Sazawal S, Ryckman KK, Das S, Khanam R, Nisar I, Jasper E, et al. Machine learning guided postnatal gestational age assessment using newborn screening metabolomic data in South Asia and sub-Saharan Africa. *BMC Pregnancy Childbirth.* 2021;21(1):609.
40. Ungureanu A, Marcu AS, Patru CL, Ruican D, Nagy R, Stoean R, et al. Learning deep architectures for the interpretation of first-trimester fetal echocardiography (LIFE) - a study protocol for developing an automated intelligent decision support system for early fetal echocardiography. *BMC Pregnancy Childbirth.* 2023;23(1):20.
41. Vijayram R, Damaraju N, Xavier A, Desiraju BK, Thiruvengadam R, Misra S, et al. Comparison of first trimester dating methods for gestational age estimation and their implication on preterm birth classification in a North Indian cohort. *BMC Pregnancy Childbirth.* 2021;21(1):343.
42. Wang Y, Shi Y, Zhang C, Su K, Hu Y, Chen L, et al. Fetal weight estimation based on deep neural network: a retrospective observational study. *BMC Pregnancy Childbirth.* 2023;23(1):560.
43. Wang Y, Zhang Q, Yin C, Chen L, Yang Z, Jia S, et al. Automated prediction of early spontaneous miscarriage based on the analyzing ultrasonographic gestational sac imaging by the convolutional neural network: a case-control and cohort study. *BMC Pregnancy Childbirth.* 2022;22(1):621.
44. Zhang Y, Tayarani M, Wang S, Liu Y, Sharma M, Joly R, et al. Identifying urban built environment factors in pregnancy care and

maternal mental health outcomes. *BMC Pregnancy Childbirth*. 2021;21(1):599.

45. Belciug S, Ivanescu RC, Serbanescu MS, Ispas F, Nagy R, Comanescu CM, et al. Pattern Recognition and Anomaly Detection in fetal morphology using Deep Learning and Statistical learning (PARADISE): protocol for the development of an intelligent decision support system using fetal morphology ultrasound scan to detect fetal congenital anomaly detection. *BMJ Open*. 2024;14(2):e077366.

46. Boujarzadeh B, Ranjbar A, Banihashemi F, Mehrnough V, Darsareh F, Saffari M. Machine learning approach to predict postpartum haemorrhage: a systematic review protocol. *BMJ Open*. 2023;13(1):e067661.

47. Huang C, Luo B, Wang G, Chen P, Ren J. Development and validation of a prediction model for intrapartum cesarean delivery based on the artificial neural networks approach: a protocol for a prospective nested case-control study. *BMJ Open*. 2023;13(2):e066753.

48. Ranjbar A, Taeidi E, Mehrnough V, Roozbeh N, Darsareh F. Machine learning models for predicting pre-eclampsia: a systematic review protocol. *BMJ Open*. 2023;13(9):e074705.

49. Kao WH, Kuo CF, Chang CC, Liu YC, Wang CC, Hsu JT, Chuang YF. Cancer survivorship and risk of pregnancy complications, adverse obstetric outcomes, and maternal morbidities in female adolescents and young adults: a nationwide population-based study from Taiwan. *Br J Cancer*. 2023;129(3):503-10.

50. Gaunt T. Prenatal imaging advances: physiology and function to motion correction and AI-introductory editorial. *Br J Radiol*. 2023;96(1147):0.

51. Davidson L, Boland MR. Towards deep phenotyping pregnancy: a systematic review on artificial intelligence and machine learning methods to improve pregnancy outcomes. *Brief Bioinform*. 2021;22(5).

52. Jia P, Manuel AM, Fernandes BS, Dai Y, Zhao Z. Distinct effect of prenatal and postnatal brain expression across 20 brain disorders and anthropometric social traits: a systematic study of spatiotemporal modularity. *Brief Bioinform*. 2021;22(6).

53. Zhou M, Qiu W, Ohashi N, Sun L, Wronski ML, Kouyama-Suzuki E, et al. Deep-Learning-Based Analysis Reveals a Social Behavior Deficit in Mice Exposed Prenatally to Nicotine. *Cells*. 2024;13(3).

54. Alex AM, Ruvio T, Xia K, Jha SC, Girault JB, Wang L, et al. Influence of gonadal steroids on cortical surface area in infancy. *Cereb Cortex*. 2022;32(15):3206-23.

55. Zhao Y, Wang M, Hu K, Wang Q, Lou J, Fan L, Liu B. The development of cortical functional hierarchy is associated with the molecular organization of prenatal/postnatal periods. *Cereb Cortex*. 2023;33(8):4248-61.

56. Mastrolorito F, Togo MV, Gambacorta N, Trisciuzzi D, Giannuzzi V, Bonifazi F, et al. TISBE: A Public Web Platform for the Consensus-Based Explainable Prediction of Developmental Toxicity. *Chem Res Toxicol*. 2024;37(2):323-39.

57. Xia TH, Tan M, Li JH, Wang JJ, Wu QQ, Kong DX. Establish a normal fetal lung gestational age grading model and explore the potential value of deep learning algorithms in fetal lung maturity evaluation. *Chin Med J (Engl)*. 2021;134(15):1828-37.

58. Barber N, Freud L. Advances in Fetal Cardiac Imaging and Intervention. *CJC Pediatr Congenit Heart Dis*. 2024;3(1):33-42.

59. Jacquemyn X, Kutty S, Manlhiot C. The Lifelong Impact of Artificial Intelligence and Clinical Prediction Models on Patients With Tetralogy of Fallot. *CJC Pediatr Congenit Heart Dis*. 2023;2(6Part A):440-52.

60. Boddupally K, Rani Thuraka E. Artificial intelligence for prenatal chromosome analysis. *Clin Chim Acta*. 2024;552:117669.

61. He F, Lin B, Mou K, Jin L, Liu J. A machine learning model for the prediction of down syndrome in second trimester antenatal screening. *Clin Chim Acta*. 2021;521:206-11.

62. Thomas MSC, Coecke S. Associations between Socioeconomic Status, Cognition, and Brain Structure: Evaluating Potential Causal Pathways Through Mechanistic Models of Development. *Cogn Sci*. 2023;47(1):e13217.

63. Karolis VR, Fitzgibbon SP, Cordero-Grande L, Farahibozorg SR, Price AN, Hughes EJ, et al.

Maturation networks of human fetal brain activity reveal emerging connectivity patterns prior to ex-utero exposure. *Commun Biol.* 2023;6(1):661.

64. Koivu A, Sairanen M, Airola A, Pahikkala T, Leung WC, Lo TK, Sahota DS. Adaptive risk prediction system with incremental and transfer learning. *Comput Biol Med.* 2021;138:104886.

65. Zhang Z, Xiao Q, Luo J. Infant death prediction using machine learning: A population-based retrospective study. *Comput Biol Med.* 2023;165:107423.

66. Liang S, Peng J, Xu Y, Ye H. Passive Fetal Movement Recognition Approaches Using Hyperparameter Tuned LightGBM Model and Bayesian Optimization. *Comput Intell Neurosci.* 2021;2021:6252362.

67. Lu Y, Zhi D, Zhou M, Lai F, Chen G, Ou Z, et al. Multitask Deep Neural Network for the Fully Automatic Measurement of the Angle of Progression. *Comput Math Methods Med.* 2022;2022:5192338.

68. Wang Q, Liu D, Liu G. Value of Ultrasonic Image Features in Diagnosis of Perinatal Outcomes of Severe Preeclampsia on account of Deep Learning Algorithm. *Comput Math Methods Med.* 2022;2022:4010339.

69. Wang X, Liu Z, Du Y, Diao Y, Liu P, Lv G, Zhang H. Recognition of Fetal Facial Ultrasound Standard Plane Based on Texture Feature Fusion. *Comput Math Methods Med.* 2021;2021:6656942.

70. Wu H, Wu B, Lai F, Liu P, Lyu G, He S, Dai J. Application of Artificial Intelligence in Anatomical Structure Recognition of Standard Section of Fetal Heart. *Comput Math Methods Med.* 2023;2023:5650378.

71. Yang X, Chen Z, Jia X. Deep Learning Algorithm-Based Ultrasound Image Information in Diagnosis and Treatment of Pernicious Placenta Previa. *Comput Math Methods Med.* 2022;2022:3452176.

72. Bertoncelli CM, Costantini S, Persia F, Bertoncelli D, D'Auria D. PredictMed-epilepsy: A multi-agent based system for epilepsy detection and prediction in neuropsychiatry. *Comput Methods Programs Biomed.* 2023;236:107548.

73. Cao Q, Sun H, Wang H, Liu X, Lu Y, Huo L. Comparative study of neonatal brain injury fetuses using machine learning methods for perinatal data. *Comput Methods Programs Biomed.* 2023;240:107701.

74. Liang H, Lu Y. A CNN-RNN unified framework for intrapartum cardiotocograph classification. *Comput Methods Programs Biomed.* 2023;229:107300.

75. Wang Y, Li YZ, Lai QQ, Li ST, Huang J. RU-Net: An improved U-Net placenta segmentation network based on ResNet. *Comput Methods Programs Biomed.* 2022;227:107206.

76. Taeidi E, Ranjbar A, Montazeri F, Mehrnosh V, Darsareh F. Machine Learning-Based Approach to Predict Intrauterine Growth Restriction. *Cureus.* 2023;15(7):e41448.

77. Karthik KV, Rajalingam A, Shivashankar M, Ganjiwale A. Recursive Feature Elimination-based Biomarker Identification for Open Neural Tube Defects. *Curr Genomics.* 2022;23(3):195-206.

78. Youssef A, Pilu G. Brain views that benefit from three-dimensional ultrasound. *Curr Opin Obstet Gynecol.* 2021;33(2):135-42.

79. Arain Z, Iliodromiti S, Slabaugh G, David AL, Chowdhury TT. Machine learning and disease prediction in obstetrics. *Curr Res Physiol.* 2023;6:100099.

80. Ambroise Grandjean G, Oster J, Dap M, Morel O, Hossu G. Artificial intelligence and fetal ultrasound biometry: Challenges and perspectives. *Diagn Interv Imaging.* 2023;104(4):200-1.

81. Bertoncelli CM, Bertoncelli D, Bagui SS, Bagui SC, Costantini S, Solla F. Identifying Postural Instability in Children with Cerebral Palsy Using a Predictive Model: A Longitudinal Multicenter Study. *Diagnostics (Basel).* 2023;13(12).