REVIEW ARTICLE

Artificial Intelligence in Perinatal Medicine and Human Reproduction: Is it "The End of the Beginning" or "The Beginning of the End"?

Milan Stanojevic[1,2,3,4], **Asim Kurjak**[2,3,4], **Edin Medjedovic**[4,5,6]

[1]Department of Obstetrics and Gynecology, Medical School University of Zagreb, Zagreb, Croatia
[2] Department of Obstetrics and Gynecology, University Hospital "Sveti Duh", Zagreb, Croatia
[3] Sarajevo School of Science and Technology, Sarajevo, Bosnia and Herzegovina
[4] International Academy of Science and Art in Bosnia and Herzegovina
[5]Clinic of Gynecology and Obstetrics, Clinical Center University of Sarajevo, Sarajevo, Bosnia and Herzegovina
[6] Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

Corresponding Author: Milan Stanojevic MD, PhD. Department of Obstetrics and Gynecology, Medical School University of Zagreb, Zagreb, Croatia; E-mail: mstanoje29@yahoo.com; Phone: +385 913712110; ORCID ID: https://orcid.org/0000-0002-3124-5575.

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Abstract

The paper explores the evolving role of Artificial Intelligence (AI) in perinatal medicine and human reproduction, highlighting its potential to transform clinical practices. AI technologies are being utilized to improve diagnostic accuracy, personalize treatment, and enhance patient care, particularly in areas like perinatal ultrasound, fetal heart rate monitoring, and fetal neurology. The Kurjak Antenatal Neurodevelopmental Test (KANET) exemplifies how AI can aid early detection of neurodevelopmental disorders. However, the integration of AI presents challenges such as data quality concerns, algorithmic bias, ethical concerns, and the need for robust regulatory frameworks. The authors argue that while AI offers significant opportunities, its implementation must be carefully managed to avoid over-reliance on technology and ensure equitable healthcare access. The paper concludes that the current state of AI in this field marks not an endpoint but a critical phase of growth and development, necessitating a balanced approach that combines innovation with ethical and practical considerations.

Keywords: artificial intelligence, perinatology, healthcare.

Introduction

Artificial Intelligence (AI) refers to the simulation of human intelligence processes by machines, particularly computer systems (1). These processes include learning (the acquisition of information and rules for using that information), reasoning (using rules to reach approximate or definite conclusions), and self-correction (1). Essentially, AI systems are designed to perform tasks that would typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation (1, 2). AI was developed to create systems that can perform tasks requiring human intelligence, thereby increasing efficiency, accuracy, and capabilities beyond human limits (1). The primary motivations include automating repetitive tasks, enhancing decision-making, addressing complex problems, and fostering innovation and ad-

vancement (1, 3). AI significantly impacts various aspects of human life, including education, agriculture, retail, e-commerce, manufacturing, entertainment, media, transportation, logistics, environment, sustainability, security, surveillance, human resources, and the non-profit sector (3). AI assists in tackling complex and data-intensive problems beyond human capacity, such as climate modeling, genetic research, and large-scale logistical planning (3). AI's ability to process and analyze vast amounts of data far quicker than humans provides valuable insights and aids decision-making processes across different areas (1, 3).

Medicine and Artificial Intelligence

AI is increasingly utilized in medicine and healthcare, extending beyond primary applications like diagnostics, personalized treatment plans, drug discovery, and patient monitoring (4 - 6). AI plays an extensive and transformative role in healthcare, enhancing clinical practices, operational efficiencies, and patient engagement (4 - 6). It is becoming an integral part of the healthcare ecosystem, offering new possibilities for improved patient outcomes and more efficient healthcare delivery (4 - 6).

Artificial Intelligence in Perinatal Medicine and Reproductive Health

Recent research demonstrates that AI has significant potential to improve the accuracy and timeliness of diagnoses in perinatal medicine and human reproduction, such as advancing perinatal ultrasound techniques, monitoring fetal heart rates during labor, or predicting modes of delivery (4 - 10). The integration of AI with obstetric ultrasound can optimize fetal ultrasound assessments by reducing examination time, improving diagnostic accuracy, and alleviating physician workload (7, 11). As technology advances, AI algorithms are expected to become even more sophisticated, potentially improving patient outcomes, enhancing healthcare efficiency, and enabling individualized care plans (7, 11). However, the successful implementation of AI in perinatal medicine and reproductive health requires addressing challenges related to interpretability and reliability (7, 11). AI can improve the prediction and early diagnosis of pregnancy complications through machine learning by analyzing large datasets to identify risk factors (7, 11). The potential of AI to tailor treatments and interventions based on individual patient data can lead to more personalized and effective care plans for mothers and infants (7, 11). Additionally, AI enhances telemedicine and remote patient monitoring, particularly in managing high-risk pregnancies or providing care access in underserved areas (7, 11). AI is also used in sophisticated robotic systems for performing complex surgical procedures, such as fetal surgery or in vitro fertilization (IVF), offering numerous benefits alongside some risks associated with these technologies (7, 11). The integration of AI in medical practice also impacts the training and education of healthcare professionals, posing challenges for clinicians as educators, as new skill sets and shifts in the role of clinicians are required (7, 11). Further research is necessary to explore areas such as long-term outcomes of AI-assisted interventions and ensuring these technologies benefit all population segments (7, 11). Additionally, the current regulatory landscape governing the use of AI in medicine, potential legal issues, and the need for updated guidelines to ensure the safe and ethical use of AI technologies in perinatal medicine and reproductive health are critical considerations (7, 11). Ethical challenges, including data privacy concerns, the potential for bias in AI algorithms, and the need for transparent and fair use of AI in clinical settings, must also be addressed (7, 11).

The Case of Fetal Neurology: Kurjak Antenatal Neurodevelopmental Test and AI

Investigating fetal neurology and behavior is crucial for understanding neurodevelopmental outcomes and potential neurological con-

ditions post-birth. One significant method in this field is the Kurjak Antenatal Neurodevelopmental Test (KANET) (12 – 20). KANET is a structured assessment tool that evaluates fetal neurobehavioral patterns using advanced ultrasound technology, particularly the four-dimensional (4D) ultrasound (12 – 20). Studies on fetal neurology and behavior, such as those conducted using KANET, can identify abnormal neurological development and potential neurobehavioral disorders early in gestation (12 – 20). This early detection is vital for planning interventions that can improve outcomes or manage conditions postnatally (12 – 20).

KANET focuses on observing fetal movements and behaviors, which are indicators of brain function and maturation (12 – 20). Specific movements, facial expressions, and the complexity of motor activities are associated with the development of the central nervous system (12 – 20). Abnormalities in these patterns can suggest higher risk of developmental delays, other neurological conditions or even cerebral palsy (12 – 20).

The test helps predict neurodevelopmental outcomes after birth by assessing specific neurobehavioral markers during the fetal period (12 – 20). This predictive capability is valuable for healthcare providers and parents, enabling them to anticipate and prepare for potential challenges that might arise post-birth (12 – 20).

In high-risk pregnancies, such as those involving maternal diabetes, preeclampsia, or intrauterine growth restriction (IUGR), KANET provides critical insights into the neurological health of the fetus (12 – 20). This information is essential for making informed decisions about the timing and mode of delivery and postnatal care (12 – 20).

By identifying potential neurodevelopmental issues before birth, KANET can guide early therapeutic interventions, including physiotherapy, occupational therapy, or other specialized care, immediately post-birth, aiming to improve developmental outcomes (15).

The KANET scoring system assesses fetal neurobehavioral development by observing fetal movements and facial expressions (21). AI can facilitate objective assessments of fetal facial expressions (21). A study reported a high accuracy and reliability score for AI in analyzing fetal facial expressions, categorizing them into seven types: eye blinking, mouthing, neutral face, scowling, smiling, tongue expulsion, and yawning (21). However, challenges remain, including the time-consuming nature of observing fetal faces, the lack of consensus among examiners on image classification, and the imperfect classification of fetal facial expressions (21). Moreover, the feasibility of recognizing fetal facial expressions using AI depends on data supervised by experienced examiners. Some datasets, such as those for rare expressions like sucking, remain problematic (21).

KANET offers a non-invasive, accessible, and informative method for evaluating fetal neurobehavior and predicting neurodevelopmental outcomes (12 – 20). Its application can significantly impact clinical decision-making, parental counseling, and planning early interventions, ultimately contributing to better health outcomes for children (12 – 20). The growing body of research supports the continued use and refinement of KANET as a valuable tool in perinatal medicine (12 – 20). However, using AI in conjunction with the KANET test presents challenges, particularly concerning data privacy, potential bias, ethical considerations, and the need for robust regulatory frameworks (21). Addressing these challenges requires a comprehensive approach that balances technological innovation with ethical standards and safeguards, ensuring AI enhances rather than detracts from patient care.

Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis of AI Use in Perinatal Medicine and Reproductive Health

Strengths

Artificial Intelligence (AI) offers several significant strengths in perinatal medicine and reproductive health. These strengths

have the potential to revolutionize the field by enhancing diagnostic accuracy, personalizing treatment, improving patient outcomes, and streamlining clinical workflows (22). AI can improve predictive analytics and operational efficiency, which are crucial in managing high-risk pregnancies and optimizing patient care. However, it is essential to address challenges related to data privacy, algorithmic bias, and the need for robust regulatory frameworks to fully realize these benefits while ensuring patient safety and ethical standards.

Weaknesses

Despite its promising applications, AI in perinatal medicine and reproductive health presents several challenges and weaknesses (23):

- Data quality and availability: AI models require large, high-quality datasets. However, data can be sparse, incomplete, or biased, limiting the models' effectiveness.
- Bias and fairness: AI systems can inadvertently incorporate biases from the training data, such as those related to race, socioeconomic status, or gender, potentially leading to unequal healthcare outcomes.
- Lack of interpretability and transparency: AI-driven recommendations may lack transparency, making it difficult for healthcare providers and patients to trust these systems, especially if they do not understand how decisions are made.
- Regulatory and ethical concerns: The lack of clear regulations and ethical guidelines can lead to legal challenges and ethical dilemmas, particularly concerning patient consent and data privacy.
- Technical and integration challenges: Without proper integration into healthcare systems, AI tools may be underutilized or misused, leading to inefficiencies or errors in patient care.
- Over-reliance on technology: There is a risk of healthcare professionals becoming over-reliant on AI, which could lead to a de-skilling of the workforce and weaken patient-doctor relationships.
- Patient acceptance and trust: Low patient acceptance and trust in AI tools can reduce their effectiveness, as patients may be reluctant to follow AI-generated recommendations or share their data.
- Cost and accessibility: Implementing and maintaining AI systems can be expensive, potentially limiting their availability to wealthier institutions or countries.

Addressing these weaknesses is crucial to ensure the safe, fair, and effective implementation of AI in clinical practice. This requires collaboration among technologists, healthcare providers, regulators, and ethicists to develop robust systems, clear guidelines, and transparent practices that protect and benefit patients.

Opportunities

The application of AI in perinatal medicine and reproductive health presents numerous opportunities to enhance care quality, efficiency, and accessibility. AI's capabilities in data analysis, pattern recognition, and automation support healthcare professionals in various aspects of patient management. Key opportunities include (24):

- Improving diagnostic accuracy: AI can analyze medical images and other diagnostic data with high precision, aiding early detection of complications and diseases.
- Personalizing treatment: AI can help tailor treatment plans based on individual patient data, improving outcomes and patient satisfaction.
- Increasing efficiency: AI can streamline administrative tasks and clinical workflows, allowing healthcare providers to focus more on patient care.

- Expanding accessibility: AI-driven tools can enhance access to care, particularly in underserved regions, through telemedicine and remote monitoring.

To fully realize these opportunities, it is essential to ensure data quality, mitigate bias, and maintain transparency and trust in AI systems (22- 24). With careful implementation and ongoing oversight, AI has the potential to transform these fields, improving outcomes for mothers and infants worldwide.

Threats

The integration of AI into perinatal medicine and reproductive health, while promising, also poses several significant threats and challenges (22-24):

- Technical limitations: AI systems are only as good as the data and algorithms they are based on, and technical errors can lead to incorrect diagnoses or treatment plans.
- Ethical considerations: Issues such as data privacy, informed consent, and the potential for AI to perpetuate existing biases are critical concerns that must be addressed.
- Impact on healthcare systems: The widespread adoption of AI may disrupt traditional healthcare delivery models, requiring significant adjustments in training and practice for healthcare professionals.

Concluding Remarks on the Use of AI in Perinatal Medicine and Reproductive Health

Winston Churchill once said, "Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning." This sentiment is echoed in the evolving landscape of AI in perinatal medicine and human reproduction. We are at a significant turning point where AI technologies are becoming integral to clinical practice (5, 6). This phase of maturity involves building on initial developments to create real-world applications and improvements.

However, this progress comes with caution. The rapid advancement of AI in sensitive areas like perinatal medicine and human reproduction raises potential ethical, practical, and societal challenges (7 – 9). Concerns such as over-reliance on technology, potential ethical dilemmas, and the need for robust regulatory frameworks must be carefully considered (7 – 9).

As Stanisław Jerzy Lec wisely noted, "The only fool bigger than the person who knows it all is the person who argues with him." This thought underscores the importance of humility and open-mindedness in our understanding and application of AI. While AI has transformative potential, it is crucial to consider the ethical, legal, and practical challenges it presents. Balancing technological innovation with ethical standards and safeguards will be key to ensuring that AI enhances, rather than detracts from, patient care in perinatal medicine and reproductive health. The future holds both promising advancements and significant challenges in this emerging field.

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