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Prospective Application of Artificial Intelligence in Foetal Monitoring: A Review Article

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I. INTRODUCTION

Artificial intelligence (AI) in fetal monitoring uses machine learning algorithms to analyze fetal heart rate (CTG) patterns, ultrasounds, and maternal vital signs. It provides real-time, automated analysis to help doctors accurately detect fetal distress, predict complications like hypoxia, and reduce preventable birth injuries.

The electronic fetal monitoring (EFM) is used nowadays particularly for monitoring the heart activity of fetus and assessing its well-being. The main objective of monitoring is an early detection of life-threatening fetal hypoxia. If the fetal hypoxia is not detected and rectified on time, the oxygen saturation of blood becomes extremely low and the fetal hypoxia progresses to asphyxia. The consequence of a serious asphyxia is a hypoxic-ischemic damage of organs which may, inter alia, lead to a brain and heart damage and a nervous system failure An accurate and reliable fetal monitoring during pregnancy and birth may lead to an early detection of states which may adversely affect the health of fetus or cause perinatal death.

Electronic fetal monitoring is used to evaluate fetal well-being by assessing fetal heart activity. The signals produced by the fetal heart carry valuable information about fetal health, but due to non-stationary and present interference, their processing, analysis and interpretation is considered to be very challenging. Therefore, medical technologies equipped with Artificial Intelligence algorithms are rapidly evolving into clinical practice and provide solutions in the key application areas: noise suppression, feature detection and fetal state classification. The use of artificial intelligence and machine learning in the field of electronic fetal monitoring has demonstrated the efficiency and superiority of such techniques compared to conventional algorithms, especially due to their ability to predict, learn and efficiently handle dynamic Big data. Combining multiple algorithms and optimizing them for given purpose enables timely and accurate diagnosis of fetal health state. This review summarizes the currently used algorithms based on artificial intelligence and machine learning in the field of electronic fetal monitoring, outlines its advantages and limitations, as well as future challenges which remain to be solved.

Overall, much of the interest in the use of AI in obstetrics and gynecology has been in the areas of fetal monitoring, which as a very small signal-to-noise ratio (similar to ECGs and EEGs), and IVF. Similar to many of the aforementioned clinical areas, obstetrics and gynecology has a very heterogeneous group of patients and even include fetuses as an essential part of the clinical scope. This level of complexity is well suited for more sophisticated ML/DL to decrease the burden and stress of decision-making for the clinician.

For the future an AI-enabled fetal monitoring strategy will reduce the human burden and concomitantly increase diagnostic accuracy for fetal events in a proactive manner. Advances in monitoring technology will lead to continuous at-home monitoring that is both accurate and noninvasive

II. KEY METHODS

- Real-Time CTG Interpretation: AI software (like Tweris) evaluates Cardiotocograph images to identify abnormal fetal heart rates and hypoxic stress, doing so with an accuracy that often exceeds visual human interpretation.

- Automated Ultrasound Biometry: Machine learning tools assist in scanning by automatically measuring fetal structures, minimizing human error, and reducing the time specialists need to interpret complex ultrasound data.
- At-Home and Remote Monitoring: Wearable devices and smartphone apps (like Nuvo's INVU) utilize AI-driven acoustic and bio potential sensors to track fetal movement and heart rates. This allows high-risk mothers to perform non-stress tests (NSTs) without traveling to a clinic.
- Hypoxia and Complication Prediction: By analyzing vast datasets, AI models can detect subtle variations in fetal heart rate variability to identify fetuses at risk of academia and cerebral palsy long before critical damage occurs

While AI augments human expertise and enables personalized risk assessments, medical professionals emphasize that these algorithms are designed to support—not replace—obstetricians and midwives in making clinical delivery decisions.

Key Application Areas in Fetal Monitoring

1. Cardiotocograph (CTG) and Fetal Heart Rate (FHR)

- Signal Analysis & Noise Suppression: Electronic fetal monitoring (EFM) often suffers from low signal-to-noise ratios, especially during maternal movement or in obese patients. AI algorithms excel at filtering out artifact noise to isolate the true fetal heart rate.
- Hypoxia and Distress Detection: AI models (such as convolutional neural networks) identify subtle, dangerous patterns in FHR decelerations and variability in real time, detecting fetal hypoxia with up to\(97\%\) accuracy.
- Automated Triage: AI-driven applications help triage patients by quickly classifying fetal states into standard clinical categories, aiding decision-making.

2. Ultrasound Biometry and Imaging

- Automated Measurements: AI automates the calculation of standard fetal biometry (eg, biparietal diameter, femur length), reducing human measurement error and speeding up appointments.
- Congenital Anomaly Detection: Trained on vast image datasets, AI accurately flags congenital heart defects (like congenital heart disease) and brain abnormalities that may elude the naked eye.

3. Predictive Risk Modeling

- Preterm Birth and Growth Restriction: By integrating clinical histories, maternal biomarkers, and ultrasound data, AI creates predictive risk models for fetal growth restriction (FGR) and preterm birth, allowing for much earlier clinical intervention.

Benefits of AI Integration

- Reduced Human Burden: Automating routine fetal monitoring duties relieves fetal medicine specialists of tedious manual interpretations, letting them focus on high-risk interventions.
- Consistency: AI minimizes inter-observer and intra-observer variability, standardizing the quality of prenatal screening regardless of where the patient receives care.
- Longitudinal Tracking: AI algorithms compensate for fetal motion to consistently track growth across multiple trimesters, producing tailored, patient-specific growth curves.

Current Challenges

- Data Bias: Many AI models rely on limited, homogenous datasets, raising concerns about algorithm performance across diverse populations.
- "Black-Box" Limitations: The opacity of certain deep learning models makes it difficult for clinicians to understand exactly how an algorithm reached a specific conclusion, creating a need for Explainable AI (XAI).
- Ethical and Legal Frameworks: Regulatory validation, patient data privacy, and establishing liability standards are ongoing hurdles in clinical implementation

III. CONCLUSION

It has been suggested that the implementation of specifically developed artificial intelligence (AI) applications holds the promise for enhancing the prenatal detection of fetuses affected by intrauterine growth disorders. Such advancements have the potential to refine antenatal management strategies, thereby improving both perinatal care as well as short- and long-term neonatal outcomes. AI-driven technologies could transform the clinical approach to the aforementioned conditions by facilitating earlier and more accurate identification of high-risk pregnancies. Nowadays, this field is evolving dynamically in parallel with technological advancements, which translates into an increasingly profound knowledge base of AI in the domain of obstetrics and gynecology (23). Through the integration of advanced computational algorithms, AI systems are capable of discerning intricate patterns within maternal, fetal, and placental datasets that may elude conventional diagnostic modalities. This capability may enable more accurate risk stratification and the timely initiation of appropriate interventions. Additionally, by minimizing inter-operator variability and optimizing the allocation of healthcare resources, AI may play a pivotal role in the evolution of precision perinatal medicine.

Finally, automated support in therapeutic decision-making and outcome prediction may facilitate the implementation of more time-efficient and safer strategies, which could be incorporated into future clinical guidelines. Nonetheless, currently adoption of AI remains limited owing to the high cost of implementation and the absence of sufficient technical infrastructure

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