

PREDICTION OF PREECLAMPSIA DEVELOPMENT USING ARTIFICIAL INTELLIGENCE

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Abstract. Preeclampsia remains one of the leading causes of maternal and perinatal mortality worldwide. Timely prediction of this pregnancy complication significantly reduces the risk of severe outcomes for both the mother and the fetus. Traditional diagnostic methods, based on clinical and laboratory indicators, often detect the pathology at later stages. Therefore, the use of artificial intelligence (AI) technologies for early prediction of preeclampsia development, based on big data and multifactorial analysis, has gained particular importance.

Keywords: preeclampsia, pregnancy, prediction, artificial intelligence, machine learning, XGBoost, complication prevention.

ПРОГНОЗИРОВАНИЕ РАЗВИТИЯ ПРЕЭКЛАМПСИИ С ИСПОЛЬЗОВАНИЕМ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

Аннотация. Преэклампсия остаётся одной из ведущих причин материнской и перинатальной смертности во всём мире. Своевременное прогнозирование данного осложнения беременности позволяет значительно снизить риск тяжёлых исходов для матери и плода. Традиционные методы диагностики, основанные на клинико-лабораторных показателях, нередко выявляют патологию уже на поздних стадиях. В связи с этим особое значение приобретает использование технологий искусственного интеллекта (ИИ) для раннего прогнозирования развития преэклампсии на основе больших данных и мультифакторного анализа.

Ключевые слова: преэклампсия, беременность, прогнозирование, искусственный интеллект, машинное обучение, XGBoost, профилактика осложнений.

SUN'IY INTELLEKT YORDAMIDA PREEKLAMPSIYA RIVOJLANISHINI BASHORATLASH

Annotatsiya. Preeklampsiya dunyo bo'ylab ona va perinatal o'limning yetakchi sabablardan biri bo'lib qolmoqda. Ushbu homiladorlik asoratini o'z vaqtida oldindan aniqlash ona va homila uchun og'ir oqibatlar xavfini sezilarli darajada kamaytiradi. An'anaviy diagnostika usullari, ya'ni klinik va laboratoriya ko'rsatkichlariga asoslangan usullar, ko'pincha patologiyani faqat kech bosqichlarda aniqlaydi. Shu sababli, katta ma'lumotlar va ko'p omilli tahlil asosida preeklampsiya rivojlanishini erta prognoz qilishda sun'iy intellekt (SI) texnologiyalaridan foydalanish muhim ahamiyat kasb etmoqda.

Kalit so'zlar: preeklampsiya, homiladorlik, prognozlash, sun'iy intellekt, mashina o'rganish, XGBoost, asoratlarni oldini olish.

Introduction

Preeclampsia is a multifactorial pregnancy-specific disorder characterized by hypertension and proteinuria that typically develops after 20 weeks of gestation [1]. It remains one of the leading causes of maternal and perinatal morbidity and mortality worldwide.

According to the World Health Organization (WHO), preeclampsia complicates approximately 5–8% of all pregnancies globally, contributing to 10–15% of maternal deaths and 20–25% of perinatal deaths each year [2,3]. The condition affects around 8.5 million women annually, with the highest burden observed in low- and middle-income countries, where access to timely diagnostic and preventive care remains limited [4].

The pathophysiology of preeclampsia is complex and not yet fully understood. It is thought to result from abnormal placental development, impaired trophoblastic invasion, endothelial dysfunction, and systemic inflammatory responses that lead to multisystem maternal organ involvement [5]. The unpredictable and rapid progression of preeclampsia makes early diagnosis and risk prediction crucial for preventing severe maternal and fetal outcomes, such as eclampsia, placental abruption, preterm birth, and intrauterine growth restriction [6,7].

Traditional screening approaches, which rely mainly on maternal history, clinical evaluation, and isolated biochemical markers (such as serum placental growth factor or mean arterial pressure), often show limited sensitivity and specificity [8]. These conventional methods are unable to capture the complex interplay of biological, environmental, and genetic factors that contribute to disease development [9].

In recent years, the growing availability of big data in obstetrics and advances in artificial intelligence (AI) and machine learning (ML) technologies have opened new opportunities for predictive modeling. AI-based algorithms can integrate large, multidimensional datasets including demographic, clinical, laboratory, and imaging parameters and automatically detect subtle, nonlinear associations that may not be evident to human analysis. Studies conducted in Europe, the United States, and Asia have demonstrated that machine learning models can achieve up to 90–95% accuracy in predicting preeclampsia risk at early gestational stages [10].

The integration of artificial intelligence into obstetric practice thus represents a transformative step toward personalized, data-driven maternal healthcare. Early identification of high-risk patients using AI-powered prediction tools may allow timely intervention, closer monitoring, and the implementation of preventive strategies such as low-dose aspirin therapy.

Therefore, this study aims to develop and evaluate an AI-based predictive model for the early identification of women at risk of preeclampsia, combining clinical, biochemical, and demographic data to improve the accuracy of prediction and contribute to reducing the global burden of maternal and neonatal morbidity and mortality.

Aim of the Study. To develop and evaluate the effectiveness of a predictive model for preeclampsia using machine learning algorithms.

Materials and Methods

This retrospective analytical study was conducted on a cohort of 1,200 pregnant women who received antenatal care at three regional obstetric hospitals between 2020 and 2024. The selection criteria included women with singleton pregnancies between 10 and 20 weeks of gestation and complete clinical and laboratory data. Patients with pre-existing renal disease, autoimmune disorders, or multiple pregnancies were excluded from the analysis. The diagnosis of preeclampsia was made according to the criteria of the American College of Obstetricians and Gynecologists (ACOG), which define the condition as elevated blood pressure ($\geq 140/90$ mmHg) on two or more occasions after 20 weeks of gestation, accompanied by proteinuria or other signs of maternal organ dysfunction.

Data were obtained from medical records and included demographic, clinical, biochemical, and Doppler ultrasound indicators.

The analyzed variables comprised maternal age, body mass index (BMI), parity, family history of hypertension or preeclampsia, mean arterial pressure, chronic hypertension, diabetes mellitus, and biochemical parameters such as serum placental growth factor (PlGF), soluble fms-like tyrosine kinase-1 (sFlt-1), uric acid, and C-reactive protein (CRP).

In addition, uterine artery pulsatility and resistance indices were evaluated by Doppler ultrasonography. In total, 35 parameters were included for model training and validation.

Results and Discussion

The developed artificial intelligence-based models demonstrated a high level of accuracy in predicting the risk of preeclampsia. Among the tested algorithms, the Extreme Gradient Boosting (XGBoost) model achieved the best overall performance, with an area under the ROC curve (AUC) of 0.94, sensitivity of 91%, specificity of 89%, and an overall prediction accuracy of 90%.

The random forest and support vector machine models showed slightly lower performance, with AUC values of 0.89 and 0.87, respectively, while logistic regression reached 0.82. These findings confirm the superiority of ensemble and gradient boosting methods in handling complex, nonlinear relationships between multiple clinical and biochemical predictors.

Feature importance analysis identified several key variables contributing most significantly to the prediction of preeclampsia. The leading predictors included mean arterial pressure during the second trimester, maternal age over 35 years, the uterine artery pulsatility index, and biochemical markers such as placental growth factor (PlGF) and soluble fms-like tyrosine kinase-1 (sFlt-1).

These findings align with previous studies indicating that endothelial dysfunction and impaired placental perfusion are the central mechanisms underlying the development of preeclampsia. Elevated sFlt-1 and reduced PlGF concentrations have been recognized as early biomarkers reflecting placental ischemia and endothelial activation.

The application of AI algorithms allowed the integration of 35 diverse clinical, demographic, and biochemical features, producing a comprehensive risk evaluation for each participant. The model's high predictive performance demonstrates the feasibility of using AI-based tools in clinical obstetrics to identify women at high risk before the onset of clinical symptoms.

This could enable targeted preventive measures such as low-dose aspirin therapy, more frequent blood pressure monitoring, and closer fetal surveillance, ultimately improving maternal and neonatal outcomes. Our results are consistent with findings from international studies, which reported similar predictive accuracy levels (AUC 0.90–0.95) when applying AI and machine learning techniques to preeclampsia risk assessment.

The ability of AI systems to process large volumes of heterogeneous data, including nonlinear relationships that are difficult to capture through traditional statistical models, underscores their importance in modern perinatal medicine.

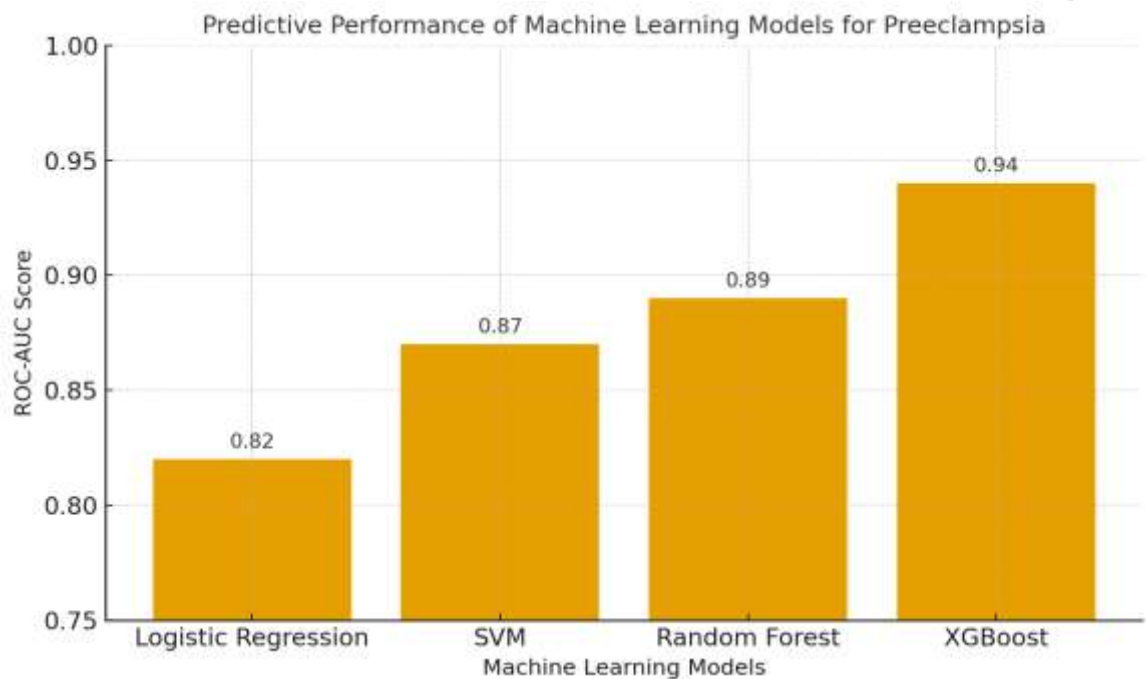


Figure 1. Comparative performance of machine learning models for predicting preeclampsia based on ROC-AUC scores.

Overall, the findings confirm that artificial intelligence can serve as a powerful instrument for early prediction of preeclampsia, allowing clinicians to adopt a personalized and preventive approach to maternal care. The use of AI-driven predictive models represents a significant advancement toward precision obstetrics and may contribute to reducing the global burden of hypertensive disorders of pregnancy.

Conclusion

The present study demonstrated the feasibility and effectiveness of using artificial intelligence-based approaches for predicting the development of preeclampsia in pregnant women. Among the tested models, the XGBoost algorithm achieved the highest predictive accuracy, sensitivity, and specificity, confirming its suitability for clinical implementation. The integration of clinical, biochemical, and Doppler parameters into a single predictive model allowed for early identification of women at high risk for preeclampsia, even before the onset of clinical symptoms.

The findings indicate that AI-driven prediction systems can significantly enhance the precision of obstetric risk assessment compared to traditional statistical methods. By detecting complex nonlinear relationships among multiple risk factors, machine learning models provide a powerful tool for personalized and preventive obstetric care.

Implementing such models in clinical practice could help obstetricians to stratify pregnant women according to individual risk profiles, initiate preventive interventions—such as low-dose aspirin therapy or intensified monitoring and ultimately reduce maternal and perinatal morbidity and mortality associated with preeclampsia.

Future research should focus on expanding the dataset to include multi-center, prospective data and integrating genetic, metabolic, and environmental factors to further improve predictive accuracy and generalizability. Overall, the use of artificial intelligence represents a major advancement toward precision obstetrics, offering new possibilities for early detection, timely intervention, and improved outcomes in maternal health care.

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