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Use of Artificial Intelligence Methods in Risk Assessment and Prediction of Preeclampsia

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Abstract

General Background: Preeclampsia is a leading cause of maternal and perinatal morbidity and mortality worldwide, with early prediction remaining a critical challenge in obstetric care. **Specific Background:** Conventional diagnostic approaches based on clinical and isolated biochemical markers often identify the disorder at advanced stages and fail to capture its multifactorial pathophysiology. **Knowledge Gap:** There is limited integration of multidimensional clinical, biochemical, and Doppler data into robust predictive models capable of early and individualized risk assessment. **Aims:** This study aimed to develop and evaluate a machine learning–based model for early prediction of preeclampsia using comprehensive antenatal data. **Results:** In a retrospective cohort of 1,200 pregnant women, the Extreme Gradient Boosting (XGBoost) model demonstrated superior performance, achieving an AUC of 0.94, sensitivity of 91%, specificity of 89%, and overall accuracy of 90%, outperforming random forest, support vector machine, and logistic regression models. Key predictors included mean arterial pressure, maternal age, uterine artery pulsatility index, placental growth factor, and soluble fms-like tyrosine kinase-1. **Novelty:** The study integrates 35 heterogeneous parameters into an AI-driven framework, highlighting the strength of ensemble learning in capturing nonlinear risk patterns. **Implications:** AI-based predictive tools offer significant potential for early identification of high-risk pregnancies, enabling targeted preventive interventions and advancing precision obstetrics to reduce preeclampsia-related adverse outcomes.

Highlight :

- XGBoost showed high accuracy for early preeclampsia risk prediction.
- Combined clinical, biochemical, and Doppler data enabled early risk identification.
- Early prediction supports timely preventive obstetric interventions.

Keywords : Preeclampsia, Pregnancy, Prediction, Artificial Intelligence, Machine Learning

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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]. Annually the condition affects around 8.5 million women, with the highest burden seen in low- and middle-income countries with limited access to early diagnostic and preventive care [4].

The pathophysiology of preeclampsia has not yet been fully elucidated and is thought to be complex. The syndrome is believed to be caused by dysfunctional placentation, suboptimal trophoblastic invasion, endothelial dysfunction, and inappropriate systemic inflammatory responses resulting in multi-organ maternal involvement [5]. Given the unpredictable and rapid course of preeclampsia, it is essential to accurately diagnose the condition before it progresses and begins to threaten the health of mothers and babies either directly (eclampsia, placental abruption) or indirectly (preterm birth, intrauterine growth restriction) [6][7].

Conventional testing methods have restricted sensitivity and specificity, relying extensively on maternal background, clinical assessment, or solitary biochemical markers (serum placental growth factor or mean arterial strain) [8]. These traditional approaches cannot comprehend the complex interactions between biological, environmental, and genetic factors that drive disease progression [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. Machine learning models have been shown in studies from Europe, the United States, and Asia to have up to 90–95% accuracy in predicting the risk of preeclampsia at early gestational periods [10].

And so the introduction of artificial intelligence into obstetric practice is a paradigm shift paving the way for individualized, data-driven maternal healthcare. AI-driven early prediction tools can help identify such patients, allowing timely intervention, enhanced surveillance, and preventive strategies such as low-dose aspirin therapy [11].

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 [12]. The definition of preeclampsia was based on ACOG criteria: blood pressure (≥140/90 mmHg) on 2 or more occasions after 20 weeks of gestation with additional laboratorial evidence of proteinuria or maternal organ dysfunction.

Based on the past records, several data were collected like the demographic, clinical, biochemical and Doppler ultrasonic indicators [13]. The variables assessed included maternal age, body mass index (BMI), parity, family history of hypertension or preeclampsia, mean arterial pressure (MAP), chronic hypertension, diabetes mellitus, and laboratory data such as serum placental growth factor (PlGF), soluble fms-like tyrosine kinase-1 (sFlt-1), uric acid, and C-reactive protein (CRP). Also, the uterine artery pulsatility and resistance indices were investigated by Doppler ultrasonography. All parameters for model training and validation that totalled to 35 include.

Results and Discussions

The developed artificial intelligence–based models demonstrated a high level of accuracy in predicting the risk of preeclampsia [14]. 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-based models performed a little worse, achieving AUC values of 0.89 and 0.87, respectively, whereas logistic regression reached an AUC of 0.82. These results reinforce the strength of the ensemble and the gradient boosting methods in capturing complex, nonlinear relations among subset of clinical and continuous biochemical predictors.

Several of the most important variables in preeclampsia prediction were identified through feature importance analysis. 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. Increased sFlt-1 and reduced PlGF concentrations have been considered as early biochemical markers of placental ischaemia and endothelial activation [15].

AI algorithms were applied to 35 clinical, demographic, and biochemical features, resulting in a customized risk assessment for each participant. The high predictive performance of our model shows that AI-based tools can help clinicians to identify AS at risk before clinical symptoms appear. This prediction could guide targeted preventive interventions such as use of low-dose aspirin, intensive blood pressure monitoring and closer fetal surveillance to better maternal and neonatal outcomes. The predictive accuracy of our results corresponded with international studies that have used AI and machine learning on preeclampsia risk assessment and similar prediction accuracy (AUC 0.90–0.95). As depicted in Figure 1, the increasing importance of AI systems in modern perinatal medicine lies in their ability to process large volumes of heterogeneous data, including information on nonlinear relationships that cannot be meaningfully captured using classical mathematical or statistical assumptions.

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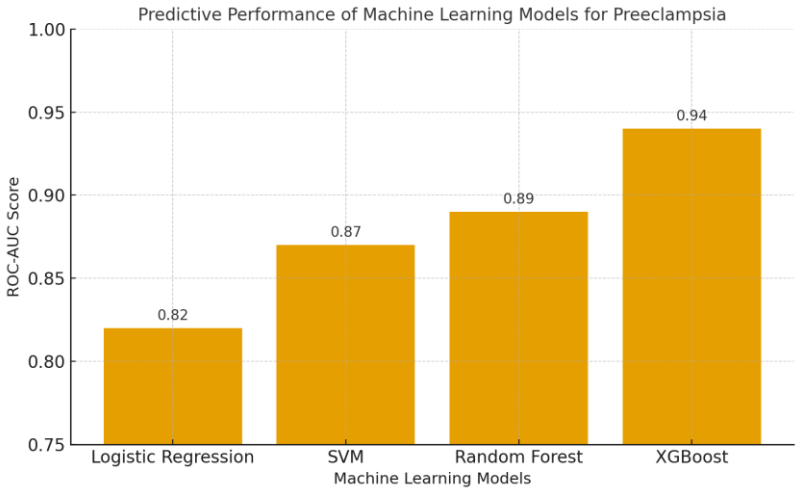

Figure 1. Comparative performance of machine learning models for predicting preeclampsia based on ROC-AUC scores.

The results generally validate that AI is a potential tool with unique capability for early prediction of preeclampsia in clinical scenario as the once glimmer of hope for clinicians to tailor individualized preventive measures for maternal care. AI-powered predictive models are critical step towards precision obstetrics and may decrease 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.

Results demonstrate that prediction systems driven by AI can markedly improve obstetric risk assessment compared with standard statistical approaches. Machine learning models are a robust way to offer personalized and preventive obstetric care by identifying intricate nonlinear associations between multiple risk factors.

Incorporating these models into clinical workflows may facilitate obstetricians to categorize pregnant women into groups based on respective risk characteristics, provide targeted preventive therapies such as low-dose aspirin therapy, or tighter surveillance and thereby decrease the rates of 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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