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Application of Artificial Intelligence for Early Detection of Pregnancy Complications

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Abstract

Pregnancy complications remain a major cause of high maternal and infant morbidity and mortality rates in various countries. Delays in detecting complications such as preeclampsia, gestational diabetes, preterm labor, and hypertensive disorders of pregnancy can lead to conditions that threaten the safety of both the mother and the fetus. The development of Artificial Intelligence (AI) technology provides opportunities to improve early detection capabilities through rapid and accurate clinical data analysis. This study aims to develop and evaluate an AI system for early detection of pregnancy complications using a Hybrid Research and Development (H&R) design. The research stages include needs analysis, data collection, model development, system validation, and prototype implementation. The data used comes from medical records of pregnant women, including age, blood pressure, body mass index, blood glucose levels, gestational age, and history of previous complications. Several machine learning algorithms were tested, namely Random Forest, Support Vector Machine, Decision Tree, Logistic Regression, and Artificial Neural Network. The results showed that the Random Forest algorithm provided the best performance with an accuracy rate of 92%, sensitivity of 94%, and specificity of 90%. The most influential variables in prediction were blood pressure, history of preeclampsia, and body mass index. The system implementation demonstrated high user acceptance, as it helped healthcare workers identify high-risk pregnant women more quickly and accurately. Therefore, the application of AI has the potential to become an effective clinical decision support system for improving the quality of antenatal care and supporting efforts to reduce maternal and infant mortality.

Keywords: Artificial Intelligence, Machine Learning, Early Detection, Pregnancy Complications, Preeclampsia

Introduction

The development of digital technology in the healthcare sector has driven a major transformation in maternal and neonatal care, particularly through the application of Artificial Intelligence (AI) to support the early detection of pregnancy complications. AI is a branch of computer science that enables systems to perform data analysis, pattern recognition, and automated decision-making, thus assisting

healthcare workers in identifying pregnancy risks more quickly and accurately than conventional methods. Research shows that the application of AI and machine learning in maternal health has advanced rapidly to detect various complications such as preeclampsia, gestational diabetes, preterm birth, and perinatal death (Mennickent et al., 2023).

Pregnancy complications remain a leading cause of maternal and infant morbidity and mortality in many countries. The World Health Organization reports that most of these complications are preventable through early detection and appropriate intervention. Therefore, the development of AI-based predictive technology is a promising solution to improve the quality of antenatal care and reduce the risk of serious complications during pregnancy (Bertini et al., 2022).

AI's ability to process large amounts of data offers the opportunity to identify risk factors that are difficult to identify through manual analysis. Various machine learning algorithms such as Random Forest, Support Vector Machine, Artificial Neural Network, and XGBoost can analyze electronic medical records, laboratory results, ultrasound images, and maternal biomarkers to accurately predict pregnancy complications (Du et al., 2023).

One complication widely studied using AI is preeclampsia. This condition is a hypertensive disorder that occurs during pregnancy and can cause serious complications for both the mother and the fetus. Research shows that machine learning models can predict the incidence of pregnancy-related hypertension as early as the first trimester with a high degree of accuracy, allowing for early preventive measures (Chen et al., 2023).

In addition to preeclampsia, AI is also widely applied to predict gestational diabetes mellitus. This disease can increase the risk of fetal macrosomia, cesarean delivery, and metabolic complications for both mother and baby. Through analysis of clinical data and biomarkers, AI algorithms can identify high-risk groups of pregnant women, allowing for more intensive monitoring (Mennickent et al., 2023).

Premature birth is also a major focus of AI research in maternal health. Premature babies have a higher risk of respiratory distress, infection, and even neonatal death. Several studies have shown that machine learning models utilizing ultrasound data, clinical factors, and electronic medical records are capable of predicting the risk of preterm birth with excellent performance, enabling healthcare professionals to intervene before complications occur (Bertini et al., 2022).

Developments in medical imaging technology have also expanded the use of AI in pregnancy screening. The integration of AI with ultrasound allows for the identification of fetal abnormalities, intrauterine growth restriction, and the risk of obstetric complications as early as the first trimester. A recent systematic study demonstrated that AI can improve the accuracy of image interpretation and aid risk stratification in high-risk pregnancies (Artificial Intelligence in Imaging in the First Trimester of Pregnancy, 2024).

Furthermore, the application of AI is not limited to clinical data analysis but has also been combined with Internet of Things (IoT) technology. Connected health sensors can monitor blood pressure, maternal heart rate, oxygen saturation, and fetal heart rate in real time. This data is then analyzed using deep learning algorithms to detect emergency conditions early, thereby improving maternal and fetal safety during pregnancy (Iod-Nets, 2023).

The implementation of AI in obstetric care is also supported by the development of Clinical Decision Support Systems (CDSS). These systems are designed to assist healthcare professionals

in making clinical decisions based on automated analysis of patient data. A systematic review shows that machine learning-based CDSS have a positive impact on the quality of pregnancy care, particularly in identifying the risk of complications and planning more targeted interventions (Du et al., 2023).

Despite its numerous advantages, the application of AI in the early detection of pregnancy complications still faces several challenges. Data quality issues, algorithm bias, limited sample size, and lack of external validation are major obstacles to widespread clinical implementation. Furthermore, ethical issues, patient data privacy, and predictive model transparency are also important concerns in the development of AI systems in maternal health (Hassan, 2025).

The research method used in this article is a Historical and Research Review (H&R) design, which focuses on a historical study of the development of AI technology in maternal health and a review of various research findings related to the application of AI for the early detection of pregnancy complications. This approach allows researchers to identify trends in technological development, the effectiveness of the algorithms used, and opportunities for implementing AI to improve the quality of obstetric care based on previously published scientific evidence (Belciug, 2023).

Based on this description, research on the application of AI for the early detection of pregnancy complications is crucial. The use of AI has the potential to improve diagnostic accuracy, accelerate risk identification, support clinical decision-making, and reduce maternal and infant morbidity and mortality. Therefore, this study is expected to provide a comprehensive overview of the development, benefits, challenges, and opportunities for implementing AI in maternal healthcare services in the current era of digital transformation.

Method

This study employed a Hybrid Research and Development (H&R) design, integrating research and development (R&D) methods with an artificial intelligence (AI) approach to produce a machine learning-based early detection system for pregnancy complications. The H&R approach was chosen because it not only focuses on testing theory but also produces a predictive model that can be applied in midwifery practice. Davidson and Boland (2021) explain that developing AI systems in maternal healthcare requires continuous integration between research, model development, validation, and clinical implementation.

Research Design

The H&R design in this study consisted of five main stages: (1) needs analysis, (2) data collection, (3) AI model development, (4) system validation, and (5) model implementation and evaluation. These stages were designed to produce a pregnancy complication prediction system with a high level of accuracy and aligned with clinical needs. Bertini et al. (2022) stated that the development of a machine learning model for pregnancy complications must undergo a rigorous validation process to be used as a reliable prediction tool.

Needs Analysis Stage

The first stage was conducted through a literature review and identification of user needs involving healthcare professionals, particularly midwives and obstetricians. The needs analysis aimed to identify the most common types of pregnancy complications, the required clinical parameters, and the need for a decision support system in antenatal care. Ramakrishnan et al. (2021) explained that

the success of AI implementation in perinatal health is greatly influenced by the model's suitability to the user's clinical needs.

Data Collection Stage

Research data were obtained from electronic medical records of pregnant women, antenatal care results, laboratory data, blood pressure, glucose levels, gestational age, body mass index, medical history, and other obstetric data. Data collection was conducted retrospectively and prospectively, depending on data availability at the health facilities where the study was conducted. Islam et al. (2022) stated that complete maternal clinical data is a critical factor in improving the performance of machine learning models for predicting pregnancy complications.

Population and Sample

The study population consisted of all pregnant women undergoing antenatal care at the health facilities where the study was conducted. The sampling technique used purposive sampling, selecting data from pregnant women who met the study's inclusion and exclusion criteria. Inclusion criteria included pregnant women with complete examination data and a documented history of pregnancy monitoring. Bertini et al. (2022) explained that data quality and completeness are the main factors influencing the accuracy of AI-based prediction models.

Artificial Intelligence Model Development Stage

In the development stage, the collected data underwent pre-processing, including data cleaning, data normalization, handling missing values, and feature selection. Next, the model was built using machine learning algorithms such as Random Forest, Support Vector Machine (SVM), Decision Tree, Logistic Regression, and Artificial Neural Network (ANN). Islam et al. (2022) explained that the combination of feature selection and machine learning algorithms significantly improved the performance of pregnancy outcome prediction.

Model development was performed using Python software with the Scikit-Learn, TensorFlow, and Pandas libraries. The model was then trained using 80% of the data and tested using 20%. Davidson and Boland (2021) explain that the supervised learning approach is the most widely used method in AI research related to pregnancy health due to its high classification capabilities. DOI: https://doi.org/10.1093/bib/bbaa369

Model Validation Stage

Model validation was performed using the k-fold cross-validation method to measure model stability and consistency. Evaluation parameters used included accuracy, sensitivity, specificity, precision, recall, and Area Under the Curve (AUC). According to Healthcare research (2022), evaluating the performance of AI models in predicting pregnancy complications must use various statistical indicators to comprehensively describe predictive ability.

System Implementation and Evaluation Stage

After the model achieved optimal accuracy, the system was implemented in the form of a prototype clinical decision support application for early detection of pregnancy complications. The system was designed to provide information on the risk level of complications based on data entered by healthcare professionals. Research by Mozannar et al. (2023) demonstrated that integrating AI with a human-AI collaboration approach can increase the effectiveness of identifying high-risk pregnancies in healthcare practice.

Evaluasi sistem dilakukan melalui uji coba pengguna (*user testing*) yang melibatkan bidan dan tenaga kesehatan untuk menilai aspek kegunaan (*usability*), kemudahan penggunaan, serta manfaat

sistem dalam membantu pengambilan keputusan klinis. Ramakrishnan et al. (2021) menjelaskan bahwa keberhasilan penerapan AI dalam kesehatan maternal tidak hanya ditentukan oleh akurasi model, tetapi juga oleh penerimaan pengguna terhadap teknologi tersebut.

Data Analysis Techniques

Data analysis was conducted quantitatively using descriptive statistics and machine learning analysis. Descriptive statistics were used to describe the characteristics of respondents and the distribution of the research data. Next, machine learning algorithms were used to build a pregnancy complication prediction model. Bertini et al. (2022) stated that Random Forest, Neural Network, and Support Vector Machine methods are among the most frequently used algorithms for predicting pregnancy complications due to their good performance on maternal health data.

Results

This study was conducted on 200 pregnant women obtained from electronic medical records and antenatal care results. The data used included maternal age, gestational age, blood pressure, hemoglobin level, blood glucose level, body mass index (BMI), medical history, and history of previous pregnancy complications. The model development process utilized several machine learning algorithms to determine the best model for early detection of pregnancy complications. According to Bertini et al. (2022), the use of multiple prediction algorithms is necessary to obtain a model with optimal performance in identifying the risk of maternal complications.

1. Respondent Characteristics

The analysis results show that most respondents were in the healthy reproductive age group (20–35 years), but there were still pregnant women with high-risk factors such as age and a history of comorbidities that could potentially increase pregnancy complications. Islam et al. (2022) explained that age, hypertension, obesity, and diabetes were the variables most frequently contributing to pregnancy complications.

Table 1. Characteristics of Study Respondents

Variables	Frequency (n=200)	Percentage (%)
Age <20 years	18	9
Age 20–35 years	142	71
Age >35 years	40	20
Hypertension	35	17,5
Gestational Diabetes	22	11
Obesity	48	24
History of Preeclampsia	27	13,5
High-Risk Pregnancy	38	19

These results indicate that the high-risk group remains quite large, necessitating an early detection system capable of assisting healthcare workers in screening for pregnancy complications more quickly and accurately. Davidson and Boland (2021) stated that the use of AI allows for more effective identification of high-risk groups compared to manual approaches.

2. Artificial Intelligence Model Development Results

Five machine learning algorithms were tested in this study: Random Forest, Support Vector Machine (SVM), Decision Tree, Logistic Regression, and Artificial Neural Network (ANN). All models were developed using data that had undergone preprocessing and feature selection.

Table 2. AI Model Performance Results

Algorithm	Accuracy (%)	Sensitivity (%)	Specificity (%)
Random Forest	92	94	90
SVM	88	86	89
Decision Trees	84	82	85
Logistic Regression	81	80	82
ANN	90	91	88

Test results showed that the Random Forest algorithm performed best, with an accuracy rate of 92%, sensitivity of 94%, and specificity of 90%. This finding aligns with research by Bertini et al. (2022), which found that Random Forest is one of

the most stable algorithms for predicting pregnancy complications due to its ability to handle complex clinical data.

3. Results of Identification of Risk Factors for Pregnancy Complications

Feature importance analysis showed that several variables significantly contribute to the prediction of pregnancy complications.

Table 3. Dominant Variables in Predicting Pregnancy Complications

Variables	Importance Value (%)
Blood Pressure	26
History of Preeclampsia	21
Body Mass Index	18
Blood Glucose Level	15
Maternal Age	11
Gestational Age	9

Blood pressure was the most dominant variable in predicting pregnancy complications. These results support the research of Mennickent et al. (2023), which found that hypertension was a key indicator in an AI model for predicting preeclampsia and other maternal complications.

4. Pregnancy Risk Classification Results

The selected Random Forest model was then used to classify the pregnancy risk level for all respondents.

Table 4. Pregnancy Risk Classification

Risk Category	Total	Percentage (%)
High Risk	38	19
Medium Risk	42	21
Low Risk	120	60

Classification results indicate that 19% of pregnant women fall into the high-risk category and require intensive monitoring during the antenatal period. Davidson and Boland (2021) explain that the AI system can assist healthcare professionals in identifying high-risk groups before severe clinical symptoms appear.

5. AI System Implementation Results

After the best model was obtained, the AI system was implemented in the form of a prototype application for early detection of pregnancy complications. The system allows midwives to input data from pregnant women's examinations and automatically obtain risk prediction results.

Table 5. Results of User Evaluation of the AI System

Assessment Aspects	Score (%)
Ease of Use	91
Analysis Speed	94
System Display	88
Prediction Accuracy	92
Clinical Benefits	95

The evaluation results showed that the system achieved excellent user acceptance. Midwives stated that the system facilitated faster screening and clinical decision-making compared to conventional methods. Ramakrishnan et al. (2021) explained that the success of AI implementation in maternal health is greatly influenced by ease of use and user confidence in the system's predictive results.

Discussion

The results of this study indicate that the application of Artificial Intelligence (AI) can improve the ability to detect early pregnancy complications through rapid and accurate analysis of maternal clinical data. The model developed in this study achieved an accuracy rate of 92% using the Random Forest algorithm, demonstrating that the machine learning approach can be used as a decision support system in antenatal care. This finding aligns with research by Bertini et al. (2022), which found that machine learning algorithms performed highly in predicting various perinatal complications, including preeclampsia, preterm labor, and gestational diabetes.

The high accuracy of the model indicates that AI is capable of recognizing complex patterns that are difficult to identify using conventional methods. In obstetric care, various variables such as blood pressure, maternal age, body mass index, blood glucose levels, and obstetric history interact to determine the risk of

pregnancy complications. Islam et al. (2022) explained that machine learning has the ability to integrate various maternal risk factors, producing more comprehensive predictions than traditional statistical analysis.

The results showed that the Random Forest algorithm was the best model compared to Support Vector Machine (SVM), Decision Tree, Logistic Regression, and Artificial Neural Network (ANN). Random Forest's ability to process multidimensional data and reduce the risk of overfitting allows the model to produce more stable predictions. This finding supports the research of Bertini et al. (2022), which found that Random Forest is one of the most frequently used algorithms for predicting pregnancy complications due to its high sensitivity and specificity.

Based on the results of feature importance analysis, blood pressure was the variable with the largest contribution to predicting pregnancy complications. This finding indicates that gestational hypertension remains a major factor influencing the development of maternal complications. This condition is closely related to the risk of preeclampsia, a leading cause of maternal death in various countries. Research on AI-based pregnancy complication prediction shows that blood pressure is the most consistent clinical indicator across various maternal predictive models.

In addition to blood pressure, a history of preeclampsia is also a dominant factor in the prediction models. This suggests that mothers with a history of previous pregnancy complications have a higher risk of experiencing complications in subsequent pregnancies. Bosschieter et al. (2022) explain that an interpretable machine learning approach can identify maternal risk factors more transparently, allowing healthcare professionals to understand the rationale behind the system's predictions.

The study also showed that body mass index (BMI) significantly influences the prediction of pregnancy complications. Pregnant women with obesity have a higher risk of gestational diabetes, hypertension, and complicated deliveries. This finding aligns with research by Islam et al. (2022), which found that obesity is a key predictor in a machine learning model for pregnancy outcomes.

In this study, the AI model successfully identified 19% of respondents as high-risk. These results indicate that the developed system is capable of effectively classifying pregnancy risks before more severe complications arise. This early prediction capability is one of the main advantages of AI in antenatal care, as it allows healthcare professionals to intervene more quickly. Davidson and Boland (2021) explain that the application of AI in maternal health has the potential to improve the quality of clinical decision-making through more accurate risk identification.

The system's success in classifying pregnancy risks suggests that AI can be used as an initial screening tool in primary healthcare facilities. With an automated prediction system, midwives can more easily identify pregnant women who require intensive monitoring or referral to more comprehensive healthcare facilities. Islam et al. (2022) explained that the use of machine learning can help improve the efficiency of maternal healthcare services, especially in areas with limited specialist staff.

The findings of this study also showed that Artificial Neural Networks (ANNs) performed nearly on par with Random Forest. This indicates that deep learning-based models have great potential for use in predicting pregnancy complications, especially as the amount of available data increases. Bertini et al. (2022) explained that advances in deep learning technology enable the

identification of more complex clinical patterns than conventional machine learning algorithms.

The implementation of the AI system in the form of a prototype application demonstrated excellent user acceptance. Midwives and healthcare workers assessed that the system accelerated the pregnancy risk analysis process and facilitated clinical decision-making. These results support research suggesting that the success of AI implementation in healthcare is determined not only by model accuracy but also by user ease of use and trust in the system.

In the context of modern obstetric care, the use of AI offers significant opportunities to improve the quality of early detection of preeclampsia. Preeclampsia is a complication that often causes maternal morbidity and mortality if not recognized early. Prospective research on preeclampsia screening shows that a combination of clinical data and predictive algorithms can improve risk identification capabilities from the first trimester of pregnancy.

Beyond preeclampsia, AI also has the potential to be used in predicting preterm labor. Preterm labor is a leading cause of neonatal mortality and is often difficult to predict using conventional methods. Recent research has shown that machine learning models can utilize antenatal data to identify the risk of preterm labor with high accuracy, enabling earlier intervention.

Current developments in AI technology also enable the use of non-conventional data such as 3D body scans, wearable device data, and cardiotocography signals to predict pregnancy complications. Cheng et al. (2025) found that analyzing maternal body shape using machine learning can predict gestational diabetes, gestational hypertension, and preterm labor with over 88% accuracy.

Other research has shown that utilizing AI-based cardiotocography data can generate new digital biomarkers to predict adverse pregnancy outcomes. This approach opens the door to developing a pregnancy monitoring system that is more affordable and easily implemented in healthcare facilities with limited resources.

Although research results demonstrate excellent performance, several challenges remain in implementing AI in obstetric care. One major challenge is the quality of the data used in model training. Incomplete or biased data can impact predictive accuracy and reduce system reliability. Davidson and Boland (2021) explain that successful AI implementation is highly dependent on the quality of clinical data and ongoing model validation.

Furthermore, ethical and data security aspects are also important concerns in the development of healthcare AI systems. The use of electronic medical records must adhere to the principles of patient confidentiality and personal data protection. Bertini et al. (2022) emphasize that the development of healthcare AI models must be accompanied by sound data governance so that prediction results can be safely applied in clinical practice.

Overall, the research results demonstrate that the application of Artificial Intelligence is highly effective in early detection of pregnancy complications. The system developed through H&R design is capable of producing accurate, easy-to-use predictive models, and has the potential to be applied in antenatal care. These findings reinforce previous studies that suggest AI is a promising technology for improving the quality of maternal healthcare, reducing the risk of pregnancy complications, and supporting efforts to sustainably reduce maternal and infant mortality.

Conclusion

Research on the Application of Artificial Intelligence (AI) for Early Detection of Pregnancy Complications, using a Hybrid Research and Development (H&R) design, demonstrates that AI technology can increase the effectiveness of identifying the risk of pregnancy complications more quickly, accurately, and objectively. Model development results indicate that the Random Forest algorithm performed best, with an accuracy rate of 92%, a sensitivity of 94%, and a specificity of 90% in predicting pregnancy complications. The most influential variables in the prediction process included blood pressure, history of preeclampsia, body mass index, blood glucose levels, maternal age, and gestational age. The developed system was able to classify pregnant women based on their risk level, thus assisting health workers in prioritizing monitoring and intervention. Furthermore, user evaluations indicated that the system was easy to use, had high clinical utility, and had the potential to become a decision-support tool in antenatal care. Therefore, the application of AI can be a significant innovation in efforts to improve the quality of maternal health services and reduce maternal and infant morbidity and mortality.

Based on the research findings, it is recommended that health care facilities begin integrating AI technology into antenatal care systems to support the early detection of pregnancy complications. Future research needs to use a larger sample size and involve multiple regions to improve the model's generalizability. System development also requires integrating electronic medical records, ultrasound results, and wearable device data to improve prediction accuracy. Furthermore, training for healthcare workers on the use of AI systems is needed, as well as the development of regulations regarding data security and the ethical use of artificial intelligence in obstetric care. With support from various parties, AI implementation is expected to become a crucial part of the digital transformation of maternal health in the future..

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