Leveraging Artificial Intelligence in Clinical Decision Support Systems for Pregnancy Care: A Literature Review

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Abstract: *This literature study paper aims to explore the role of clinical decision support systems in pregnancy care and their potential for reducing maternal mortality. AI technologies have the potential to transform prenatal, perinatal, and postnatal care by enhancing the accuracy of diagnoses, personalizing treatment plans, and predicting complications before they become critical. The review synthesizes findings from various studies, highlighting the application of machine learning algorithms in analyzing complex medical data, such as ultrasound images and genomic data, to support clinical decisions.The paper will focus on the use of artificial intelligence and machine learning models in CDSSs for various study targets such as birth mode prediction, pregnancy risk prediction, fetal state monitoring, risk level prediction, childbirth prediction, treatment prediction, and infection prediction. The study will analyze the effectiveness of these CDSSs in improving pregnancy outcomes and reducing maternal mortality rates.Various machine learning and deep learning algorithms have been employed to address different tasks. Additionally, the paper will also discuss the challenges and limitations of implementing CDSSs in pregnancy care and provide recommendations for future research in this area.*

Keywords*: Artificial Intelligence, Machine Learning, Deep Learning, Clinical decision support system, Pregnancy care, Electronic Health records.*

Introduction

Pregnancy care stands as a crucial domain within healthcare, where the well-being of both the mother and the unborn child requires meticulous attention and proactive management [20]. In recent years, the integration of Artificial Intelligence (AI) into Clinical Decision Support Systems (CDSS) has emerged as a promising approach to enhance the quality and efficacy of pregnancy care [21]. This literature review seeks to provide a comprehensive overview of the applications, advancements, and implications of AI-driven CDSS in the realm of pregnancy care.In obstetrics, predictive modeling plays a pivotal role in enhancing maternal and neonatal healthcare outcomes [20]. Birth mode prediction algorithms assist clinicians in anticipating the most suitable delivery method, whether vaginal or cesarean, based on various maternal and fetal factors [1]. Childbirth prediction models aid in forecasting labor onset and progression, enabling timely interventions and resource allocation [8]. Fetal state monitoring systems utilize advanced technologies to assess fetal well-being, detecting abnormalities and guiding obstetric management decisions [5]. Pregnancy risk prediction tools evaluate the likelihood of complications such as gestational diabetes, preeclampsia, or preterm birth, facilitating early intervention and personalized care plans [4]. Risk level prediction algorithms stratify patients based on their susceptibility to adverse outcomes, empowering healthcare providers to prioritize high-risk cases and allocate resources efficiently [6]. Treatment prediction algorithms assist in selecting the most effective therapeutic interventions for conditions like ectopic pregnancy, intrauterine growth restriction, or postpartum depression, optimizing clinical outcomes and patient satisfaction [9]. Additionally, CDSS addresses various pregnancy-related concerns, including infection prediction [2][12], intrauterine failure detection [3], depression [18] and diet prescription [10], by leveraging AI-driven approaches to enhance diagnosis, treatment, and preventive strategies, ultimately improving maternal and fetal health. With the exponential growth of medical data and technological capabilities, AI algorithms offer unprecedented opportunities to analyze vast datasets, identify patterns, and derive actionable insights that can inform clinical decision-making. In the context of pregnancy care, AI-powered CDSS harnesses various machine learning (ML) and deep learning (DL) techniques to address a myriad of challenges, ranging from predicting birth modes and assessing fetal well-being to managing pregnancy-related complications and optimizing treatment strategies [21]. The integration of AI in CDSS for pregnancy care holds immense potential to revolutionize traditional healthcare practices by enabling personalized and evidence-based approaches tailored to individual patient profiles. By leveraging AI algorithms, healthcare providers can access real-time, data-driven recommendations, facilitating early detection of risks, timely interventions, and improved outcomes for both maternal and neonatal health [21]. This literature review aims to explore the diverse applications of AI in pregnancy care CDSS, encompassing predictive modeling, risk assessment, treatment optimization, and clinical decision support across various stages of pregnancy. Additionally, it seeks to critically examine the current state-of-the-art technologies, identify gaps and challenges, and propose future directions for research and implementation to harness the full potential of AI in enhancing pregnancy care outcomes. Overall, the integration of AI in CDSS heralds a new era of precision medicine in pregnancy care, offering unprecedented opportunities to optimize clinical workflows, improve patient outcomes, and ultimately advance the quality and safety of maternal and neonatal healthcare delivery. Through this literature review, we aim to contribute to the growing body of knowledge in this rapidly evolving field and provide insights that inform future research, clinical practice, and policy development.

Literature Review

In recent years, the integration of artificial intelligence (AI) into healthcare systems has revolutionized the delivery of patient care, particularly in the domain of pregnancy care. Clinical Decision Support Systems (CDSS) equipped with AI algorithms offer a promising avenue for enhancing decision-making processes and improving outcomes for expectant mothers and their infants [21]. This literature review explores the role of AI in the development and implementation of CDSS tailored for pregnancy care. With a focus on leveraging advanced machine learning techniques, including deep learning models, the review examines how these systems aid healthcare providers in predicting and managing various aspects of maternal health. By analyzing a diverse range of studies and methodologies, this review aims to provide insights into the current state-of-the-art in AI-driven CDSS for pregnancy care, along with their potential applications, challenges, and future directions. Through a comprehensive examination of existing literature, this review seeks to highlight the transformative impact of AI in maternal healthcare and its role in advancing the global agenda of reducing maternal mortality rates as shown in the below

Table 1: Global agenda of reducing maternal mortality rates

Author	Input Data Type	Key findings	Limitations	Role in Maternal Mortality Reduction
Abbas et al. [1]	EHR	Using Random Forest (RF), the paper focuses on predicting C-section or normal delivery for women.	Biases and confounding factors not addressed.	Provides accurate prediction of birth mode, enabling healthcare providers to make informed decisions and potentially reduce complications associated with delivery
Zhang et al. [2]	USI	Logistic regression (LOR) is a method used to identify tumours in this paper.	Deep learning algorithms in medicine have not been widely discussed due to potential challenges or drawbacks.	Early detection of ovarian tumors through accurate identification, potentially leading to timely interventions and improved maternal health outcomes.
Van Calster et al. [3]	EHR	Using Binary Logistic Regression (BLOR), this study aims to predict the chances of three types of pregnancies - intrauterine, failing of unknown location, and ectopic.	Data from a large study is still being collected, limiting its generalizability.	Early detection of ectopic pregnancies and other complications allows for prompt intervention, potentially preventing adverse outcomes and reducing maternal mortality
Gorthi et al. [4]	EHR	CART is a method that can be used to predict the risk of pregnancy as either high, low, or medium.	Small sample size may not accurately represent all populations.	Early identification of high-risk pregnancies allows for targeted interventions and monitoring, potentially reducing adverse outcomes and maternal mortality rates.
Nagendra et al. [5]	CTG data	Random Forests is a method used to assess the condition of a fetus, categorizing it as Normal, Suspect, or Abnormal.	No evaluation of the applicability of results.	Accurate assessment of fetal health enables timely interventions in case of abnormalities, contributing to the reduction of adverse fetal and maternal outcomes.

Ahmed et al. [6]	Sensor data	A decision tree (DT) can help predict the risk level for maternal health.	IoT devices may introduce biases and limitations in collecting data for maternal healthcare.	Early identification of maternal health risks enables proactive interventions, potentially preventing complications and reducing maternal mortality rates.
Bautista et al. [7]	EHR	Paper uses Random Forest for predicting high or low risk pregnancy.	Telemedicine framework lacks ethical and privacy considerations.	Early identification of high-risk pregnancies allows for targeted interventions and monitoring, potentially reducing adverse outcomes and maternal mortality rates.
Alberola-Rubio et al. [8]	EHR	This paper discusses the use of Support Vector Machine (SVM) to predict the type of labor onset.	Excluding patients with previous C-sections or pregnancy complications may restrict the usefulness.	Accurate prediction of labor onset type enables timely preparation for childbirth, potentially reducing risks and complications during labor and delivery.
Paydar et al. [9]	EHR	Multi-layer perceptron (MLP) is used in this paper for predicting abortion and birth.	No clinical testing has been done to assess the effects of CDSS on pregnancy outcomes for SLE patients.	Early identification of pregnancy complications such as spontaneous abortion enables timely interventions, potentially reducing adverse outcomes and maternal mortality rates.
Caballero-Ruiz et al. [10]	EHR	C4.5 Decision Tree is used for the Prediction of Diet prescription, Detection of insulin needs.	Real-world clinical setting poses challenges.	Accurate prediction of dietary requirements and insulin needs contributes to the management of gestational diabetes, potentially reducing risks associated with uncontrolled blood sugar levels and improving maternal outcomes.
Fernández et al. [11]	EHR	This paper uses support vector machine to predict the treatment for ectopic pregnancies, including surgery, medical treatment, and expectant management.	Lack of research on decision support systems for ectopic pregnancies.	The CDSS provides accurate prediction of treatment options for ectopic pregnancies, enabling timely interventions and reducing the risk of complications and maternal mortality.

Kopanitsa et al. [12]	EHR	This paper uses Gradient Boosting Regression (GBR) to predict sepsis (infection).	Study may not apply to different populations or settings.	Early identification of infection enables prompt treatment, potentially preventing adverse outcomes and reducing maternal mortality rates.
Güvenir et al. [13]	EHR	SVM is used to predict IVF success (having baby)	Model not practical; accuracy decreases with more data	Accurate prediction of IVF success enables better allocation of resources and improves the chances of successful pregnancies, potentially reducing maternal mortality rates.
Yılmaz et al. [14]	CTG Data	This paper discusses the use of probabilistic neural networks (PNN) for assessing the state of a fetus as normal, suspect, or pathological during fetal state monitoring.	Paper does not address overfitting and model complexity.	Accurate assessment of fetal health enables timely interventions in case of abnormalities, contributing to the reduction of adverse fetal and maternal outcomes.
Das et al. [15]	CTG Data	Fuzzy logic (FL) is used in this paper to predict the birth mode by classifying labor stages.	Lack of discussion on overfitting and model complexity in paper.	Accurate prediction of labor onset type enables timely preparation for childbirth, potentially reducing risks and complications during labor and delivery.
Ravindran et al. [16]	CTG Data	Genetic algorithm (GA) is used for assessing fetal well-being.	Real-world clinical setting poses challenges/limitations.	Accurate assessment of fetal health enables timely interventions in case of abnormalities, contributing to the reduction of adverse fetal and maternal outcomes.
Jiménez-Serrano et al. [17]	EHR	Artificial Neural Network (ANN) is a technique used to predict postpartum depression in this paper.	Study lacks information on sample size and demographic characteristics for determining external validity.	Early identification of postpartum depression enables timely interventions, potentially preventing adverse outcomes and reducing maternal mortality rates.
Amo et al. [18]	USI	SVM used for classifying normal and abnormal fetal heart planes in ultrasound images.	Model not suitable for real-world use; accuracy decreases with more data and may not detect plane abnormalities.	Accurate assessment of fetal health enables timely interventions in case of abnormalities, contributing to the reduction of adverse fetal and maternal outcomes.
Bingzheng et al. [19]	USI	MLP used for classifying US images	An imbalanced dataset led to incorrect	Accurate assessment of fetal health enables timely interventions in

Research Method

The objective of this comprehensive review was to gather the most up-to-date articles relevant to the topic using online databases such as IEEE, Springer, and Elsevier. A thorough literature search was conducted within the last few years. Several attempts were made before performing a title/keyword search using the query 'clinical decision support systems for pregnancy care', 'machine learning for pregnancy care', 'Role of AI in Maternal Mortality Reduction', and 'artificial intelligent systems for pregnancy care'. Additionally, the search was limited to only include papers utilizing clinical decision support systems. This yielded a total of 158 papers, which were then further analyzed. Out of the initial 158 studies, 98 were obtained from peer-reviewed journals and conference papers. After a careful evaluation of these 98 papers and an assessment of their eligibility, only 19 were deemed relevant to this review and were subsequently included.

A literature review from the articles gathered is used to answer the following research questions mentioned as follows:

RQ1. What are all the types of learning paradigms that are commonly used in clinical decision support systems?

RQ2. What are all the study targets that are addressed in the clinical decision support systems?

RQ3. How well does the CDSS developed help in reducing maternal mortality?

RQ4. What are the future directions for the clinical decision support systems using Artificial intelligence?

Results & Discussions

This Section provides answers to research questions using case studies from selected papers on CDSS development using machine learning and deep learning models for different study purposes/study targets.

A. RQ1. What are all the types of learning algorithms that are commonly used in the clinical decision support systems?

In the realm of clinical decision support systems (CDSS), various learning algorithms play a pivotal role in addressing diverse study targets and their occurences in the selected case studies are shown in the Figure 1. In CDSS case studies, machine learning algorithms are more commonly employed than deep learning algorithms, with machine learning occurring in 11 instances compared to 8 instances of deep learning. This indicates that while both paradigms are utilized, machine learning algorithms are slightly more prevalent in the context of clinical decision support systems as shown in the Figure 1.

In clinical decision support system (CDSS) case studies as shown in Figure 2, various machine learning and deep learning algorithms have been employed to address different tasks. Among them, Support Vector Machine (SVM) is the most frequently used algorithm, appearing in four case studies. Random Forest (RF) and Multi-layer Perceptron (MLP) follow closely, each being utilized in three case studies. Logistic Regression (LOR), Binary Logistic Regression (BLOR), Classification and Regression Trees (CART), Gradient Boosting Regression (GBR), Genetic Algorithm (GA), Decision Tree (DT), Fuzzy Logic (FL), Probabilistic Neural Network (PNN), and Artificial Neural Network (ANN) are each employed in one case study. These algorithms are leveraged to develop predictive models for various aspects of maternal health, ranging from birth mode prediction to treatment prediction and fetal state monitoring.

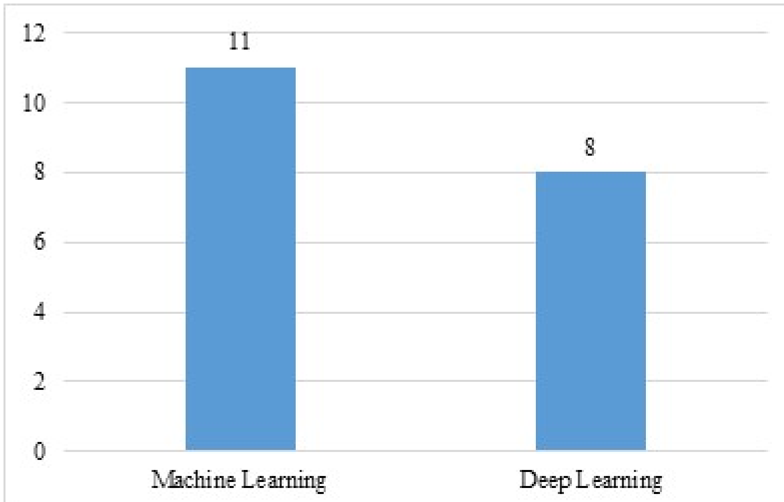

Figure 1: The Occurrences of the ML and DL Algorithms in the Case Studies

Source: Primary Source

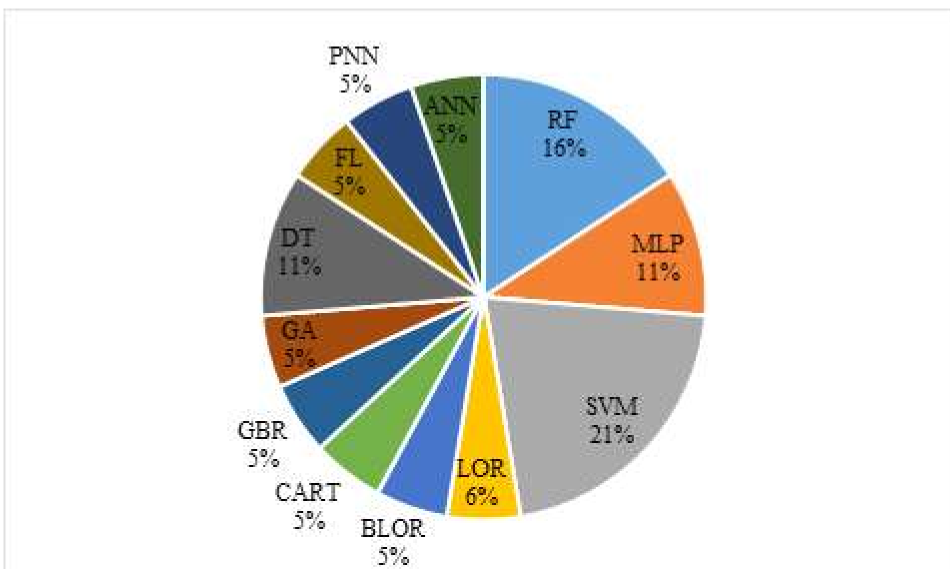

Figure 2: The Occurrences of the Several ML and DL Algorithms in the Case Studies

Source: Primary Source

Among the machine learning models, Random Forest (RF) appears to be the most frequently used, as it is applied in four different study targets: Birth mode prediction (2), Fetal State Monitoring (1), Treatment Prediction (1), and Other (3). For deep learning models, the Multi-layer Perceptron (MLP) stands out as the most commonly utilized, being employed in three different study targets: Birth mode prediction (1), Fetal State Monitoring (3), and Other (1).

A.RQ2. What are all the study targets that are addressed in the clinical decision support systems?

As shown in the Figure 3, in the realm of clinical decision support systems (CDSS), a diverse array of predictive models is deployed to address critical aspects of maternal healthcare. Birth mode prediction algorithms, including Random Forest and Support Vector Machine, aid in anticipating whether a woman is likely to undergo a cesarean section or have a normal delivery, enabling healthcare providers to prepare and mitigate associated risks. Similarly, child birth prediction models, leveraging techniques such as CART and Multi-layer Perceptron, offer insights into pregnancy outcomes, helping anticipate complications and tailor interventions for improved maternal and fetal health. Fetal state monitoring, utilizing ML and DL algorithms like Random Forest and Artificial Neural Networks, allows for real-time assessment of fetal well-being through parameters like heart rate and movement patterns, facilitating timely interventions in case of abnormalities. Pregnancy risk prediction models, often based on Logistic Regression or Random Forest, assess the likelihood of complications like preterm birth or gestational diabetes, enabling proactive management strategies. Risk level prediction algorithms, such as Support Vector Machine, aid in stratifying patients based on their susceptibility to adverse outcomes, guiding personalized care plans. Treatment prediction models, encompassing techniques like C4.5 Decision Tree and Genetic Algorithm, assist in selecting optimal interventions for conditions like ectopic pregnancies or diabetes management during pregnancy. Additionally, CDSS addresses miscellaneous concerns such as infection prediction, intrauterine failure, and diet prescription, utilizing various ML approaches to enhance clinical decision-making and ultimately improve maternal and neonatal health outcomes.

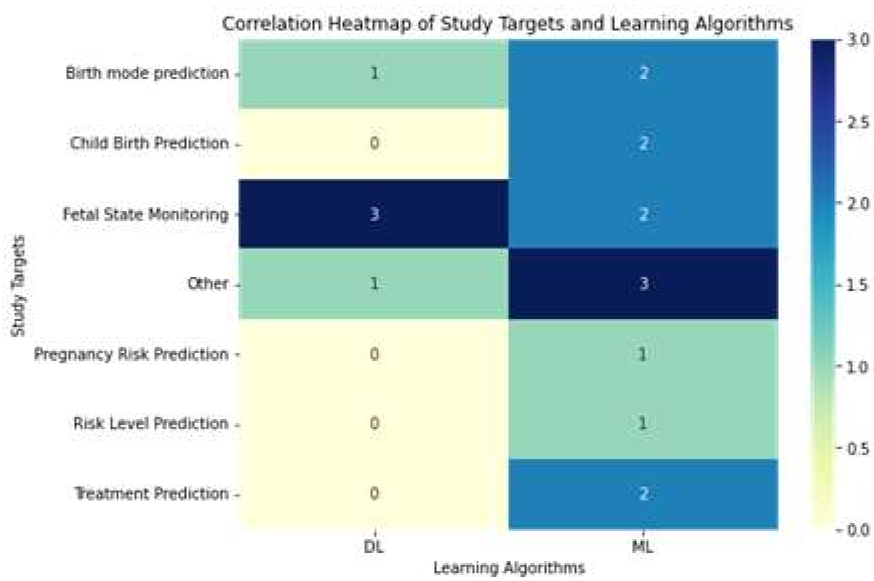

Figure 3: Frequency of the Learning Algorithms for the Various Study Targets
Source: Primary Source

C. RQ3. How well does the CDSS developed helps in reducing maternal mortality?

The developed Clinical Decision Support Systems (CDSS) in the studies play a crucial role in reducing maternal mortality rates by improving various aspects of maternal healthcare. These systems utilize advanced machine learning algorithms and diverse datasets to predict key outcomes and provide valuable insights for healthcare providers. For instance, they accurately predict birth modes, such as C-section or normal delivery, enabling informed decision-making and potentially reducing complications associated with childbirth. Furthermore, CDSS aid in early detection of conditions like ectopic pregnancies, ovarian tumors, and high-risk pregnancies, facilitating timely interventions to prevent adverse outcomes and ultimately reduce maternal mortality. They also contribute to the assessment of fetal health, prediction of pregnancy risks, and identification of postpartum depression, allowing for proactive interventions and improved maternal outcomes. Despite some limitations such as data biases, model complexities, and challenges in real-world clinical settings, these CDSS offer valuable tools for healthcare professionals to optimize maternal care and contribute significantly to the reduction of maternal mortality rates.

D. RQ4. What are the future directions for the clinical decision support systems using Artificial intelligence?

In the future, clinical decision support systems (CDSS) using Artificial Intelligence (AI), Machine Learning (ML), or Deep Learning (DL) are set to revolutionize healthcare. These systems will become even more personalized, tailoring treatments to individual patients based on their unique characteristics and needs. They'll provide real-time monitoring, alerting healthcare providers to potential issues instantly for timely interventions. Furthermore, they'll offer clear explanations for their recommendations, ensuring trust and understanding among both providers and patients. Seamless integration into existing workflows, predictive insights, continuous learning, and a focus on ethical and regulatory compliance are also key directions. Ultimately, these advancements aim to enhance patient care, improve outcomes, and make healthcare more accessible and equitable worldwide.

Conclusion & Future Scope

In conclusion, the review underscores the significant potential of leveraging artificial intelligence (AI) in clinical decision support systems (CDSS) for pregnancy care. Through an extensive examination of existing literature, it becomes evident that AI-driven approaches offer promising avenues for enhancing maternal and fetal health outcomes. Birth mode prediction, child birth prediction, fetal state monitoring, pregnancy risk prediction, risk level prediction, treatment prediction, and other pertinent areas in obstetrics benefit from the application of AI algorithms, facilitating more accurate diagnoses, personalized interventions, and proactive management strategies. However, despite the advancements made, several challenges remain, including the need for robust validation studies, addressing biases in datasets, ensuring interoperability and usability of AI-driven CDSS, and addressing ethical and privacy concerns. Looking ahead, the prospects for AI in pregnancy care are bright, with opportunities for further innovation, collaboration, and integration into routine clinical practice. Future research should focus on refining AI models, optimizing their performance in diverse populations, enhancing user acceptance and trust, and exploring novel applications to address emerging healthcare needs in obstetrics. By harnessing the power of AI in CDSS, healthcare providers can continue to improve maternal and fetal health outcomes, ultimately advancing the quality and safety of pregnancy care worldwide.

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