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Factor analysis and risk prediction of postpartum hemorrhage in pregnant women

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Abstract

Postpartum hemorrhage (PPH) remains the leading cause of maternal mortality and a common obstetric complication. Rapid onset and severity can lead to hemorrhagic shock and fatal outcomes if not promptly managed. Major causes include uterine atony, placental abnormalities, birth canal trauma, and coagulation disorders. This study proposes a risk prediction model for PPH based on a Deep Belief Network (DBN), using relevant risk factors as input features. To address limitations from random initialization in the DBN, an improved Particle Swarm Optimization (IPSO) algorithm—featuring adaptive inertia weight and learning factors—was introduced to optimize network parameters. The optimized model, referred to as IDBN, was applied to predict PPH risk levels more accurately and efficiently. The results demonstrate the superior performance of the IDBN method, which achieved the highest accuracy and F1 score among all models evaluated. This approach offers a novel, data-driven method for early PPH risk identification and clinical intervention. *(Afr J Reprod Health 2026; 30 [1]: 29-36).*

Keywords: Factor analysis; risk prediction; postpartum hemorrhage; deep neural network

Résumé

L'hémorragie du post-partum (HPP) demeure la principale cause de mortalité maternelle ainsi qu'une complication obstétricale fréquente. Son apparition rapide et sa gravité peuvent entraîner un choc hémorragique et des issues fatales si elle n'est pas prise en charge rapidement. Les causes majeures incluent l'atonie utérine, les anomalies placentaires, les traumatismes du canal génital et les troubles de la coagulation. Cette étude propose un modèle de prédiction du risque de HPP basé sur un Réseau de Croyance Profond (Deep Belief Network, DBN), utilisant des facteurs de risque pertinents comme variables d'entrée. Afin de pallier les limitations dues à l'initialisation aléatoire dans le DBN, un algorithme amélioré d'optimisation par essaim particulaire (IPSO) – intégrant un poids d'inertie adaptatif et des facteurs d'apprentissage modulables – a été introduit pour optimiser les paramètres du réseau. Le modèle optimisé, nommé IDBN, a été appliqué pour prédire les niveaux de risque de HPP de manière plus précise et efficace. Les résultats démontrent les performances supérieures de la méthode IDBN, qui a obtenu les meilleurs scores en termes de précision et de F1 parmi tous les modèles évalués. Cette approche offre une méthode innovante et fondée sur les données pour l'identification précoce du risque de HPP et pour guider les interventions cliniques. *(Afr J Reprod Health 2026; 30 [1]: 29-36).*

Mots-clés: Analyse factorielle ; prédiction du risque ; hémorragie du post-partum ; réseau neuronal profond

Introduction

Postpartum haemorrhage (PPH) is one of the most dreaded obstetric complications and one of the three main causes of maternal mortality in the world. It is universally defined as haematic loss above 500 ml following a vaginal delivery or above 1,000 ml following a caesarean[1] Due to the sudden nature of postpartum hemorrhage, if rescue measures are not taken in time, maternal shock may ensue in severe cases, posing great endanger to the life of the mother[2]. Maternal mortality is the main indicator that reflects the health level of women and the development of medical and health services in any country[3]. In the low-and-middle-income countries in Africa and Asia, postpartum hemorrhage is often the number one cause of maternal death. In recent years, postpartum hemorrhage has gradually become the leading cause of maternal death in China. Especially in remote areas, PPH accounts for more than 50% of maternal deaths[4,5]. Uterine atony is the main cause of postpartum hemorrhage, accounting for more than 80% of all cases[6]. When myometrial contractions fail to occur after delivery, it manifests as a disorganised uterine contractions, known as uterine atony. A history of uterine fibroids, past multiple pregnancies, macrosomia, polyhydramnios in the third trimester, and preeclampsia are the main risk factors for uterine atony. Some drugs, such as nifedipine, used to and magnesium sulphate used to treat severe preeclampsia and eclampsia can also cause postpartum haemorrhage. Severe coagulation dysfunction can also result from postpartum bleeding largely due to placental factors, birth canal damage, and underlying coagulation problems. The known risk factors for postpartum hemorrhage include multiple pregnancy, previous history of PPH, preeclampsia, macrosomia, and abnormal labor[7]. Occasionally, postpartum hemorrhage occurs in women without known risk factors, which makes the disease unpredictable. Although the causes of postpartum hemorrhage are complex, some measures can be taken to prevent them. Currently, pregnant women with high-risk factors for postpartum hemorrhage (PPH) require enhanced monitoring and nursing care throughout the antenatal, intrapartum, and postpartum periods (within 24 hours after delivery). Prompt identification of the underlying causes of bleeding is essential, followed by the administration of timely and effective treatments. The key to reducing the incidence of postpartum hemorrhage and maternal mortality is to take active preventive measures against the risk factors associated with postpartum hemorrhage. Therefore ,Combination of prevention and treatment can truly reduce postpartum hemorrhage and maternal mortality, reduce postpartum complications, and ensure the safety of mothers and their babies[8].

Early identification and management of postpartum haemorrhage (PPH) improves patient prognosis, reduces the burden on healthcare resources, and lowers medical costs. Optimal outcomes in severe PPH rely on multidisciplinary collaboration to formulate appropriate treatment strategies. Presently, medical therapy such as oxytocin, ergometrine and misoprostol are the recommended first line treatment for PPH[9]. Other options include intrauterine packing, balloon compression, and other forms of compression hemostasis If conservative treatment fails to relieve the bleeding, a surgical plan or interventional vascular embolization should be formulated in a timely manner. For patients with PPH who have undergone surgery or interventional therapy, it is important to determine whether they have had important organ dysfunction and complications during the bleeding process. All patients with severe postpartum hemorrhage should be transferred to the intensive care unit for close monitoring and treatment as soon as possible in the event of a life-threatening situation[10]. With ongoing advancements in medical technology, medical devices, and pharmacological therapies, the diagnostic and therapeutic capabilities for PPH have significantly improved. Nevertheless, the increasing prevalence of cesarean deliveries, the expanded use of medical interventions, and the growing complexity of maternal health profiles continue to contribute to a rising number of risk factors associated with PPH. To effectively prevent, promptly identify, and appropriately manage postpartum hemorrhage, it is essential to first understand the high-risk factors associated with its occurrence in women and to perform a comprehensive assessment of maternal health status. Prenatal, intrapartum and postpartum attention should be paid to pregnant women with many high-risk factors for postpartum hemorrhage, and corresponding treatment should be carried out in a timely manner[11]. This requires continuous research and summary in clinical work, and comprehensive analysis of related high-risk factors, etiology, treatment methods and efficacy of postpartum hemorrhage. Therefore, this study aimed to develop a predictive model for risk factors of postpartum hemorrhage (PPH) using electronic health data, providing a tool for early identification of PPH risk and early clinical intervention.

Methods

Study design

This retrospective cohort study was conducted utilizing data obtained from Beijing Ditan Hospital, Capital Medical University. Medical records of all consecutive parturients with singleton pregnancies at a gestational age of ≥28 weeks who delivered at our center between May 1, 2022, and July 31, 2024, were reviewed. A total of 862 cases were included, among which 49 cases (5.7%) experienced postpartum hemorrhage (PPH). The exclusion criteria were as follows: (1) incomplete medical records; (2) termination of pregnancy; and (3) stillbirth. The clinical information collected included age, uterine contraction status, placental conditions, soft birth canal assessment, presence of hypertension, anemia, and coagulation disorders. All data collection was conducted with the informed consent obtained from the patients or their respective families.

Definition and diagnosis of postpartum hemorrhage

The diagnostic criteria for postpartum hemorrhage (PPH) are established based on guidelines from the World Health Organization (WHO), the International Federation of Gynecology and Obstetrics (FIGO), and national clinical recommendations. PPH is defined as meeting any of the following criteria: (1) Quantitative criterion: blood loss of ≥ 500 mL within 24 hours after vaginal delivery or ≥ 1000 mL following cesarean section; (2) Qualitative criterion: any degree of blood loss accompanied by signs or symptoms of hypovolemia (e.g., tachycardia, hypotension) or a hemoglobin (Hb) decrease of ≥ 10%. Severe PPH is defined as meeting any of the following: (1) Blood loss of ≥ 1000 mL; (2) Requirement for red blood cell transfusion; (3) Development of hemodynamic instability or coagulation dysfunction. Intractable PPH is diagnosed when any of the following criteria are fulfilled: (1) Blood loss of ≥ 2500 mL; (2) Requirement for ≥ 5 units of red blood cell transfusion; (3) Development of disseminated intravascular coagulation (DIC).

Development of a risk predictive model

Risk prediction model developed in this work using the DBN architecture. It uses postpartum hemorrhage risk variables as an input feature and outputs the associated postpartum hemorrhage risk level. Second, this work applies an improved PSO technique to optimise the initial parameters due to the detrimental effects of the DBN model's random initialization of network weights and thresholds. This paper proposes an improved inertia weight and learning factor to construct the IPSO algorithm, and then utilizes IPSO to optimize initial parameters for DBN network to construct the IDBN algorithm. This study uses the IDBN algorithm to establish a bleeding risk prediction model based on the analysis of risk factors for postpartum hemorrhage. The algorithm process of each link is shown in the following figures (Figures 1-3).

Deep belief network architecture and improved particle swarm optimization

The DBN was constructed by stacking multiple Restricted Boltzmann Machines (RBMs), each consisting of a visible layer and a hidden layer with full inter-layer connections but no intra-layer connections. The energy function of each RBM was defined as:

$$E = -\sum_{ij} w_{ij} v_i h_j - \sum_i b_i v_i - \sum_j c_j h_j \quad (1)$$

The activation probabilities for neurons in the visible and hidden layers were calculated as follows:

$$p(v_j = 1|h) = f(c_i + \sum_j h_j w_{ij}) \quad (2)$$

$$p(h_j = 1|v) = f(b_j + \sum_i v_i w_{ij}) \quad (3)$$

The joint probability distribution of the RBM can also be computed when the visible and hidden layer states are given by:

$$P = \exp(-E) \,/\, \sum_{v,h} \exp(-E) \quad (4)$$

To enhance parameter optimization, we developed an IPSO algorithm incorporating adaptive strategies for inertia weight and learning factors. The velocity and position update equations were:

$$v_{id}^{k+1} = wv_{id}^{k} + c_1 r_1 (p_{id}^{k} - x_{id}^{k}) + c_2 r_2 (p_{gd}^{k} - x_{id}^{k}) \quad (5)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \quad (6)$$

The inertia weight was dynamically adjusted using:

$$w = w_{max} - (w_{max} - w_{min}) * \sin(\pi t^2 / t_{max}^2) \quad (7)$$

The algorithm will fail if the learning factor is set too high because the particles will move too quickly to the target area. The particles will wander far from the target area, be unable to get close to the goal value, and fall into a local optimum if the learning factor is too small. This work proposes an improved learning factor strategy (ILF), which allows the learning factor to vary with the search state. So that the particle swarm can learn from its best location and improve the global search ability, the first learning factor is given a bigger value in the beginning of the search, while the second learning factor is given a smaller value.

In the subsequent stages of the algorithm, the particles learn from the global best position and improve their local search capability by decreasing the value of the first learning component and increasing the value of the second learning factor.

$$c_1 = 2 - \sin(\pi t / t_{max}) \quad (8)$$

$$c_2 = 1 + \sin(\pi t / t_{max}) \quad (9)$$

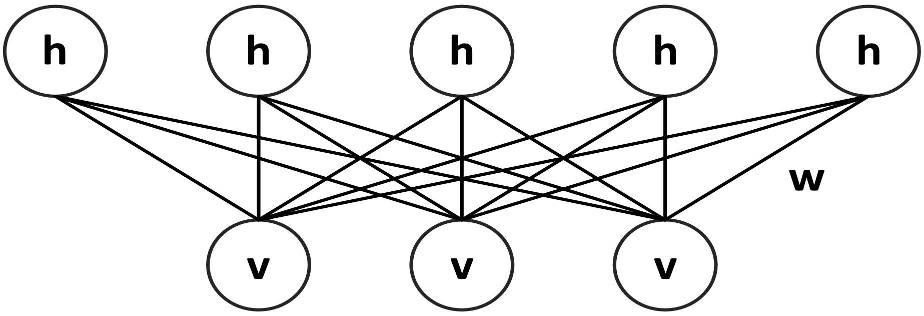

Figure 1: RBM network

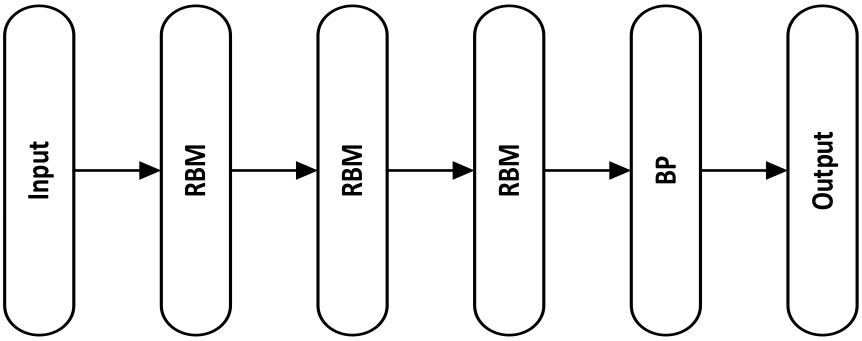

Figure 2: DBN pipeline.

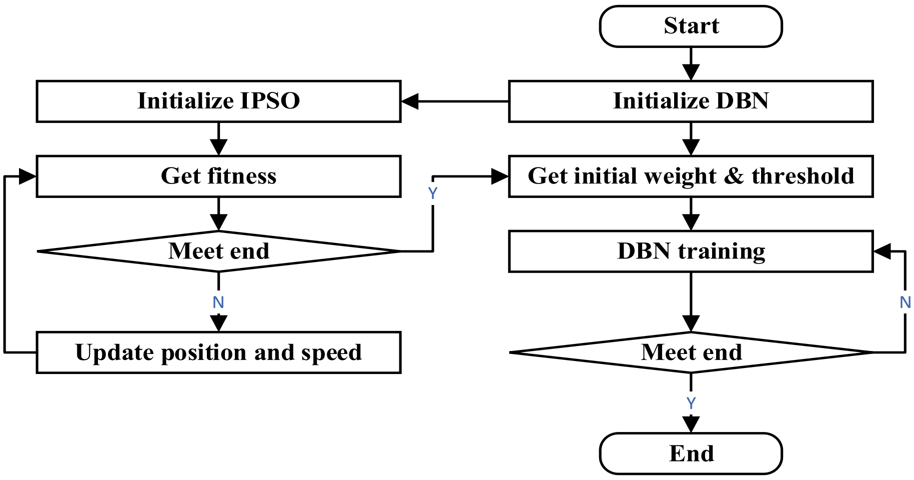

Figure 3: IDBN pipeline

Results

Dataset

This work collects the corresponding postpartum hemorrhage data of pregnant women as training and testing samples of the network. The features of each sample consisted of maternal postpartum hemorrhage factors, as shown in Table 1. Each sample is labeled with a risk class for postpartum hemorrhage in pregnant women.

Table 1: Postpartum hemorrhage factors in pregnant women

Index	Factor
x_1	Maternity age
x_2	Uterine contractions
x_3	Placental factor
x_4	Soft birth canal
x_5	High blood pressure
x_6	Anemia
x_7	Coagulation

Table 2: Training process for IDBN.

Epoch	20	40	60	80	100	120	140	160	180	200
Loss	5.42	2.77	1.82	0.91	0.80	0.70	0.69	0.68	0.68	0.69
Acc	24.10	81.30	89.10	94.00	95.20	96.70	96.60	96.70	96.70	96.70
F1	17.30	73.30	83.20	90.50	91.40	92.90	92.90	92.80	92.90	92.90

IDBN training process

This work analyzes the training situation of IDBN network. The main analysis goals are training loss, training accuracy and training F1 score. The numerical changes of these three are illustrated in Table 2. As the training progresses, the training loss of IDBN tends to decrease, while the training accuracy and F1 score tend to increase. When a certain training epoch is reached, these three tend to stabilize.

Comparison with different methods

To further verify the superiority of IDBN for postpartum hemorrhage risk assessment in pregnant women, this work compared IDBN with other different methods. The data obtained from the comparative experiments are illustrated in Figure 4. Compared with other methods listed in the figure, the proposed IDBN method can achieve the highest accuracy rate and F1 score. This shows that the IDBN method designed in this paper can achieve high performance in predicting and evaluating the risk of postpartum hemorrhage in pregnant women.

Improved inertia weight analysis

This work utilizes improved inertia weight to optimize the DBN algorithm. To verify the feasibility of the IIW strategy, this work compares the performance of IDBN networks using traditional inertial weight (TIW) and using IIW. The experimental data are illustrated in Figure 5. Compared with the IDBN performance when using TIW, after using the IIW measure, IDBN achieves 1.5% improvement in accuracy and 1.6% improvement in F1 score. This proves the correctness of IIW strategy.

Improved learning factor analysis

This work utilizes improved learning factor to optimize the DBN algorithm. To verify the feasibility of the ILF strategy, this work compares the performance of IDBN networks using traditional learning factor (TLF) and using ILF. The experimental data are illustrated in Figure 6. Compared with the IDBN performance when using TLF, after using the ILF measure, IDBN achieves 1.10% improvement in accuracy and 1.30% improvement in F1 score. This proves the correctness of ILF strategy.

RBM layer analysis

The DBN network is formed by stacking RBMs. To evaluate influence of RBM layers on the performance of the model, this work is based on different RBM layers to conduct experiments. The experimental data are illustrated in Table 3. As the number of RBM layers increases, the overall IDBN performance shows a trend of increasing first and then decreasing. When the number of RBM layers is three, IDBN can obtain the highest accuracy rate and F1 score.

Discussion

Postpartum hemorrhage remains the leading cause of maternal mortality worldwide. Currently, the main causes of postpartum hemorrhage include uterine atony, placental abnormalities, lacerations of the soft birth canal, and coagulation disorders, among which uterine atony accounts for approximately 90% of cases[1,8].

Logistic regression analysis revealed that uterine atony, placenta previa, placental abnormalities, birth canal injuries, parity, cesarean section, early maternal-infant contact, and early breastfeeding were independent risk factors for postpartum hemorrhage[13].

When cesarean section and vaginal delivery were analyzed separately, the significant predictors for cesarean delivery included placenta previa, placenta accreta or increta, fetal weight, pregnancy-induced hypertension, history of miscarriage, placental abruption, and parity, listed in descending order of influence.

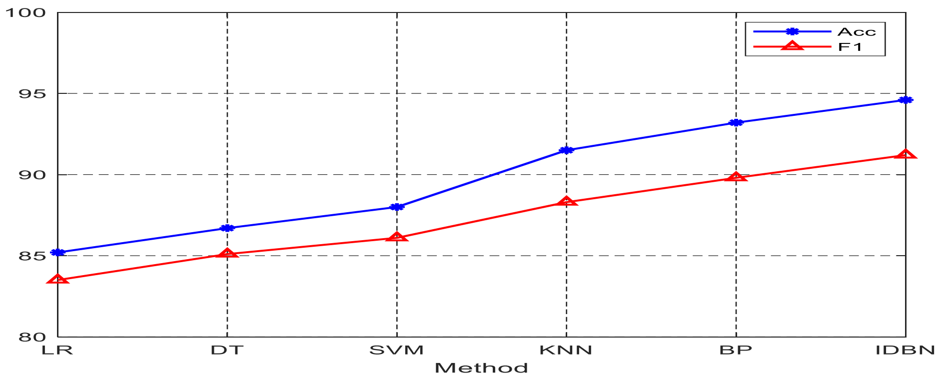

Figure 4: Comparison with different methods.

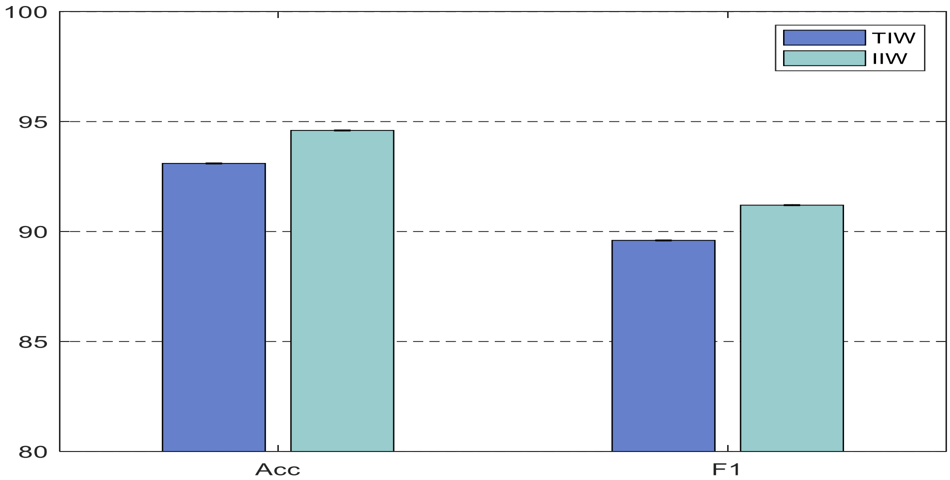

Figure 5: Improved inertia weight analysis.

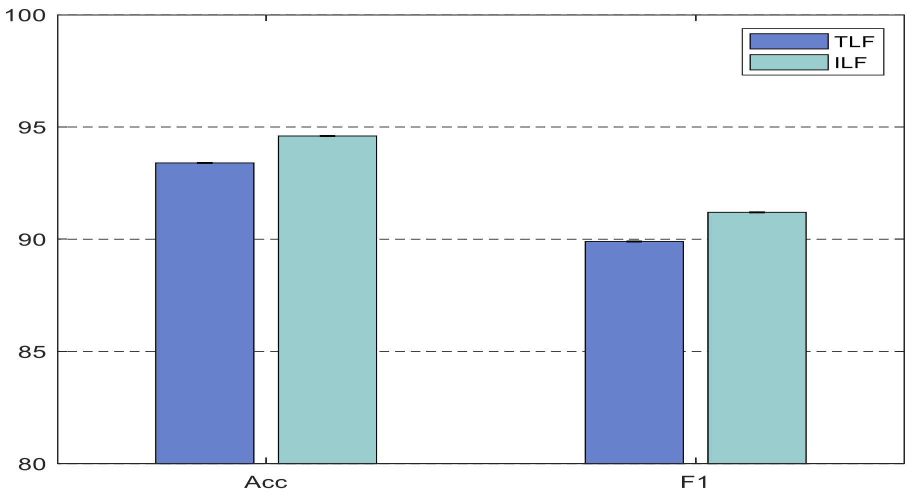

Figure 6: Improved learning factor analysis.

Table 3: RBM layer analysis.

RBM	1	2	3	4	5
Acc	91.70	93.10	94.60	94.30	93.80
F1	88.90	90.20	91.20	90.80	90.50

For vaginal delivery, the identified risk factors were placental adhesion or accreta, fetal weight, duration of the third stage of labor, and pregnancy-induced hypertension[14]. Additionally, advanced maternal age has also been recognized as a high-risk factor for postpartum hemorrhage[15,16]. Interestingly, a study conducted on pregnant women undergoing cesarean section complicated by postpartum hemorrhage categorized participants into two groups: elective and non-elective cesarean sections. Risk factors for postpartum hemorrhage in elective cesarean delivery included leiomyomas, blood disorders, placenta previa, antepartum hemorrhage, preterm labor, and general anesthesia. In non-elective cesarean deliveries, risk factors for postpartum hemorrhage encompassed hematological disorders, retained placenta, antenatal blood transfusion, antenatal or intrapartum hemorrhage, placenta previa, general anesthesia, and macrosomia. Repeated miscarriages have also been shown to increase the likelihood of postpartum hemorrhage.

A previous study indicated that recurrent abortions may cause damage to the endometrium and even the myometrium. This increases the risk of placental adhesions, placenta accreta, placenta previa, and uterine surgical fatigue during subsequent pregnancies. Placental abnormalities are often associated with a history of multiple miscarriages and cesarean sections. Placental adhesions or accreta can prolong the third stage of labor, which significantly impairs uterine contraction. Delayed placental separation prevents timely closure of the blood sinuses at the placental site, thereby contributing to severe postpartum hemorrhage[17]. Although the bleeding resulting from lacerations of the soft birth canal is generally less severe compared to that associated with placental abnormalities or coagulation disorders, it should still be regarded as clinically significant. While coagulation dysfunction accounts for a relatively low proportion of postpartum hemorrhage cases, the associated risk factors are considerable. Patients with impaired coagulation function often present with underlying severe liver disease, hepatic injury, or systemic hematologic disorders. Additionally, such cases may be linked to obstetric complications such as placental abruption, amniotic fluid embolism, or retained fetal demise[18].

Treatment options for postpartum hemorrhage are typically chosen based on the doctor's clinical expertise. Although surgical treatment can treat severe postpartum hemorrhage caused by various causes, the incidence of postoperative rebreeding is high and complications are prone to occur. Active prevention of postpartum hemorrhage is an important way to reduce women's mortality. Overall, this study developed a predictive model for PPH using a DBN architecture, incorporating rigorous statistical methodologies and presenting the findings through a clinically applicable nomogram. This model can serve as a valuable tool for obstetricians in risk assessment, resource optimization, and the implementation of personalized preventive strategies, ultimately contributing to the reduction of PPH-related morbidity and mortality. Nevertheless, certain limitations must be acknowledged. First, as a single-center retrospective study, there may be unmeasured risk factors associated with PPH, as well as potential data biases. Moreover, the prediction model has only undergone internal validation within a single institution. External validation across diverse populations and healthcare settings is required to confirm its generalizability and enhance the reliability of its predictions..

Conclusıon

This study developed a predictive model for postpartum hemorrhage (PPH) utilizing a Deep Belief Network (DBN) architecture combined with an optimized algorithm. The model utilizes recognized PPH risk factors as input features to generate corresponding PPH risk level assessments. Comparative analyses with other methodologies demonstrated the superior performance of the Improved Deep Belief Network (IDBN) in evaluating PPH risk. Furthermore, it was determined that the IDBN model achieved peak accuracy and the highest F1-score when configured with three Restricted Boltzmann Machine (RBM) layers. This model serves as a valuable tool for obstetricians in risk assessment, resource allocation optimization, and the implementation of personalized preventive strategies. It facilitates the early identification and timely intervention of PPH, ultimately contributing to a reduction in maternal mortality associated with PPH. Future research should focus on incorporating multi-center clinical data to refine unmeasured risk factors, thereby further enhancing the predictive accuracy and comprehensiveness of the model.

Availability of data and material

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

Declares that he has no conflict of interest.

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Author contributions

XD K and YW Z conceptualized the study. XD K, YW Z, and LL conducted the literature review. XD K and LL were responsible for data analysis and interpretation of the results. All authors contributed to the discussion of the findings. All authors read and approved the final manuscript.

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