

Analysis of Risk Factors and Prognosis of Venous Thromboembolism During Pregnancy and Puerperium

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Abstract: Venous thromboembolism (VTE) during pregnancy and puerperium is one of the important health risks for perinatal women, including deep vein thrombosis (DVT) and pulmonary embolism (PE), which can endanger the lives of mothers and infants in severe cases. Hypercoagulable state during pregnancy, uterine compression, hemodynamic changes and limited postpartum activities all increase the risk of VTE, especially those who have undergone cesarean section and have a history of VTE. There are differences in the prevention strategies of VTE in national guidelines. The Royal College of Obstetricians and Gynecologists (RCOG) adopts a hierarchical management model, while the American College of Obstetricians and Gynecologists (ACOG) is relatively conservative and only recommends drug prevention for high-risk groups, while Canada adopts an intermediate strategy. Based on the characteristics of the Asian population, the domestic expert consensus proposes that localized high-risk factors such as dynamic monitoring of D-dimer, BMI ≥ 28 kg/m², preeclampsia, and assisted reproductive pregnancy be included in the risk assessment system to improve the accuracy of VTE prevention and control. In terms of preventive measures, non-drug interventions (such as early mobilization and gradient compression stockings) are the basis, and low molecular weight heparin (LMWH) is currently recognized as the first choice of anticoagulant drugs, but its timing, dosage and bleeding risk are still controversial. Studies have shown that LMWH can effectively reduce the incidence of VTE, but it may increase the risk of poor postoperative wound healing and bleeding, suggesting that the clinic needs to balance the benefits and risks of prevention, especially in optimizing medication strategies in the general maternal population.

Keywords: Venous Thromboembolism (VTE) During Pregnancy, Risk Factors, Prevention Strategies, Prognostic Analysis

Introduction

Venous thromboembolism (VTE) during pregnancy and the postpartum period is a common complication during pregnancy and delivery, which can endanger the lives of mothers and babies in severe cases. Venous thromboembolism includes deep vein thrombosis (DVT) and pulmonary embolism (PE), and its

occurrence is closely related to physiological and biochemical changes during pregnancy. According to the definitions in the “Guidelines for the Prevention and Treatment of Venous Thromboembolism in Pregnancy” and the “Guidelines for the Management of Postpartum Venous Thromboembolism”, VTE refers to the symptoms of blood vessel obstruction caused by thrombosis, affecting the normal circulation of blood flow. Venous thromboembolism during pregnancy and the postpartum period mainly occurs in the veins of the lower limbs and may embolize the lungs, posing a serious threat to life. The incidence of VTE during pregnancy is relatively high, especially within 6 weeks after delivery. Studies have shown that the incidence of postpartum thromboembolism is about 0.5% to 1%. Pulmonary embolism is the second leading cause of death during pregnancy. The occurrence of this phenomenon is closely related to factors such as changes in blood rheology during pregnancy (such as hypercoagulable state), uterine compression, reduced movement, and obstructed venous return. The risk of VTE increases significantly during the postpartum period, especially after cesarean section. The risk further increases with the accumulation of risk factors such as maternal age, obesity, pregnancy complications (such as gestational hypertension, diabetes, etc.) and history of VTE ^[1-2].

Accurate prevention and control of obstetric venous thromboembolism (VTE) is a key link in perinatal safety management. International authoritative guidelines show that early screening based on risk assessment models can reduce the incidence of obstetric VTE by 40%-60%^[3-5]. The Royal College of Obstetrics and Gynecology (RCOG) proposed a three-level hierarchical management strategy, recommending the use of the “RCOG Risk Assessment Table” for dynamic scoring in early pregnancy, and starting low-molecular-weight heparin prevention from 12 weeks of pregnancy for high-risk pregnant women (such as antiphospholipid antibody syndrome and previous VTE history). Intermittent pneumatic compression devices are used for intervention in the moderate-risk population^[3]. The American College of Chest Physicians (ACCP) guidelines further refine the anticoagulation regimen, suggesting that drug prevention should be started within 6 hours after cesarean section to reduce the risk of postoperative VTE from 0.5%-1.5% to below 0.1%^[6]. my country’s “Expert Consensus on the Prevention, Diagnosis and Treatment of Venous Thromboembolism during Pregnancy and Postpartum Period” ^[2] innovatively incorporates a dynamic monitoring system for D-dimers, and combined with the coagulation characteristics of the Asian population, proposes that for high-risk factors with regional characteristics such as BMI ≥ 28 kg/m², preeclampsia or assisted reproductive pregnancy, it is recommended to start preventive anticoagulation after 28 weeks of gestation. Clinical practice has shown that this regimen reduces the incidence of VTE in the postpartum period from 0.12% to 0.04% ($P < 0.01$). It is worth noting that the ACOG guidelines ^[5] emphasize the importance of multidisciplinary collaboration, and joint management of obstetrics, hematology and vascular surgery can reduce the missed diagnosis rate of VTE by 35%. What needs to be urgently addressed in

clinical practice is the localization of risk assessment tools and the precise control of prevention timing, which is of great significance to reducing the VTE-related mortality rate of pregnant women in my country (currently 1.2/100,000).

1 High-risk factors for venous thromboembolism during pregnancy and postpartum period

1.1 Differences in international guidelines for VTE prevention

There are significant regional differences in the prevention strategies for venous thromboembolism (VTE) during pregnancy and the puerperium, which is mainly due to the differences in the understanding of risk stratification models and prevention benefit assessments among countries. The Royal College of Obstetricians and Gynecologists (RCOG) in the United Kingdom adopts a comprehensive screening strategy. Its 2021 version of the guidelines^[3] proposes the use of a dynamic risk assessment table, incorporating more than 30 factors such as BMI ≥ 30 kg/m² and multiple pregnancies into the scoring system, and recommends step-by-step intervention for pregnant women at any risk level: low-risk groups (score ≤ 2 points) only need physical prevention, medium-risk groups (3-4 points) combined with intermittent pneumatic compression devices, and high-risk groups (≥ 5 points) need low-molecular-weight heparin (LMWH) prevention from early pregnancy. This strategy has reduced the VTE-related maternal mortality rate in the UK from 1.7/100,000 in 2013 to 0.9/100,000 in 2020^[3]. The American College of Obstetricians and Gynecologists (ACOG) guidelines^[5] are more conservative, recommending drug prevention only for high-risk factors such as a history of VTE (OR=9.5, 95%CI=7.8-11.6) and antiphospholipid antibody syndrome (OR=6.3). The basis for this is that a cohort study of 420,000 pregnant women in 2018 showed that the absolute risk reduction of drug prevention for those without clear high-risk factors was only 0.03%^[5]. The Society of Obstetricians and Gynecologists of Canada (SOGC)^[4] proposed a middle-of-the-road approach, listing preeclampsia (OR=3.1) and assisted reproductive pregnancy (OR=2.8) as medium-risk factors, and recommending LMWH prevention within 6 weeks after delivery. This plan reduced the incidence of VTE from 0.15% to 0.07% (RR=0.47). This divergence reflects the dilemma of balancing “over-medicalization” and “under-prevention”, and an accurate stratification model based on evidence-based medicine is urgently needed.

1.2 Risk factor classification and localized prevention and control

The Expert Consensus on the Prevention, Diagnosis and Treatment of Venous Thromboembolism during Pregnancy and Postpartum Period^[2] innovatively constructed a four-dimensional risk assessment framework: ① Pre-pregnancy high-risk factors (history of VTE, hereditary thrombophilia). ② Pregnancy complications (active autoimmune disease, nephrotic syndrome). ③ Temporary

risk factors (surgery during pregnancy, ovarian hyperstimulation syndrome). ④ Obstetric-specific factors (preeclampsia, cesarean section, postpartum hemorrhage). Among them, the high-risk factors unique to the Chinese population are worthy of attention: data from the Obstetrics and Gynecology Hospital Affiliated to Fudan University showed ^[8] that BMI ≥ 28 kg/m² (OR = 4.2), assisted reproductive pregnancy (OR = 3.6) and gestational diabetes (OR = 2.9) accounted for 62% of local VTE patients, significantly higher than that of European and American populations. The obstetric VTE scoring table developed by Shanghai ^[8] includes postpartum hemorrhage ≥ 1000 ml (3 points), cesarean section (2 points), and advanced age ≥ 35 years (1 point) in the quantitative assessment. Clinical verification shows that when the score is ≥ 3 points, LMWH prevention can reduce the incidence of VTE from 0.8% to 0.2% (NNT=167). In view of the coagulation characteristics of the Asian population, the consensus recommends that prevention should be initiated for pregnant women with D-dimer >5 times the normal value (sensitivity 82%, specificity 76%) or fibrinogen >6 g/L, even if there are no typical symptoms ^[2]. However, a large sample study by FEDERSPIEL et al. ^[9] revealed that if the RCOG standards are strictly followed, 73.4% of women undergoing cesarean section need drug prevention, while only 0.3% according to the ACOG standards. This difference in implementation may lead to misallocation of clinical resources.

1.3 Controversy for prevention strategies in terms of the evidence base Aspect

The core controversy of VTE prevention currently lies in the benefit-risk ratio of drug intervention. The meta-analysis by MIDDLETON et al. ^[10] included 29 RCTs (n=18,752) and found that although the incidence of VTE in the LMWH prevention group was reduced (RR=0.65, 95%CI=0.48-0.87), the risk of severe bleeding increased by 1.8 times (RR=1.82, 95%CI=1.24-2.67). For every case of VTE prevented, 500 cases need to be treated, and 3 cases of severe bleeding events are increased. This suggests that high-risk groups need to be accurately identified: data from the United Kingdom Obstetric Surveillance System (UKOSS) ^[11] showed that for those with ≥ 3 risk factors, the NNT for LMWH prevention was reduced to 83, and the risk of bleeding was controllable (RR=1.12). Another controversial point is the timing of prevention. The ACCP guidelines^[6] emphasize the golden 6-hour window after delivery, because 50% of obstetric VTE occurs within 1 week after delivery, and the thrombin generation potential (TGP) within 24 hours after cesarean section is 2.3 times higher than that of vaginal delivery^[6]. However, a study by Shanghai Jiaotong University^[8] found that the peak of D-dimer in Chinese women after delivery occurs at 48-72 hours, and it is recommended to extend the prevention window to 3 days after delivery. In addition, cost-effectiveness analysis shows that although comprehensive screening strategies can reduce VTE mortality, the cost per quality-adjusted life year (QALY) is as high as \$85,000, far exceeding the WHO-recommended

threshold of 3 times GDP per capita^[3]. Therefore, the 2023 RCOG revised guidelines^[11] proposed a dynamic risk assessment model, which reduces the use rate of drug prevention from 58% to 34% through stratified management of early, mid-, and late pregnancy, while maintaining the VTE incidence rate below 0.08%. This evidence-based precision prevention and control model may become the future development direction.

2 Preventive measures for venous thromboembolism during pregnancy and the postpartum period

The measures for preventing thrombosis in the VTE guidelines for pregnancy and the postpartum period in various countries are basically the same^[2-6], that is, timely use of non-drug methods and drug intervention for VTE high-risk groups. For those who do not meet the indications for preventive medication after dynamic high-risk factor screening and evaluation during pregnancy and postpartum, appropriate non-drug methods can be used to prevent VTE. Non-drug treatment mainly involves health education for pregnant women and standardized care for them, encouraging them to get out of bed and move around early, eat a reasonable diet, and avoid risk factors such as dehydration, immobilization and infection. Therefore, clinical physicians should conduct early thrombosis risk assessment for patients, identify their clinical manifestations, and provide standardized diagnosis and treatment. Medical workers should conduct early thrombosis risk assessment for patients, identify their clinical manifestations, and provide standardized treatment. There are some physical therapies that can be used to prevent and treat venous thromboembolism. They can be used alone or in combination with drug anticoagulation: including: ① Dorsiflexion of the foot. ② Anti-thrombotic gradient compression stockings: suitable for pregnant women who can move freely. ③ Intermittent air compressor or foot venous pump: Suitable for pregnant women who are bedridden for a long time, have limb immobilization, and have high risk factors for VTE, especially those who have undergone cesarean section. It is best to use it within 2 days after delivery. At least until the second day after delivery. If pregnant women cannot wear elastic stockings with slopes, they can consider using it overnight.

For patients who have indications for preventive use of anticoagulants after dynamic evaluation, expert consensus^[2] recommends the combination of physical therapy and anticoagulants. At present, the commonly used anticoagulants for preventing VTE in clinical practice include heparin drugs, warfarin, direct factor Xa inhibitors, etc. Warfarin is a vitamin K antagonist and is currently only suitable for pregnant women who have undergone heart valve replacement surgery. Direct factor Xa inhibitors can enter the human body through the placenta and are prohibited during pregnancy. Neither heparin nor low molecular weight heparin can cross the placental barrier, and it is safer to use during pregnancy. Among them, low molecular weight heparin (LMWH) is a new type of anticoagulant

drug. Its main function is to exert an anticoagulant effect through anticoagulant factor Xa, reducing the adverse reactions such as bleeding caused by conventional heparin sodium, and has a long half-life, high bioavailability, low toxicity and side effects, and high safety. It has a long half-life, high bioavailability, low toxicity and side effects, and high safety. Therefore, it is an ideal anticoagulant drug for venous thromboembolism during pregnancy and postpartum. Therefore, when pregnancy bleeding and high-risk factors related to venous thromboembolism (VTE) coexist, we should not ignore the bleeding risk brought by the use of anticoagulants, and we should not ignore the prevention and treatment of VTE due to concerns about bleeding. We recommend that non-drug methods be used to prevent venous thromboembolism first, and then, when the risk of bleeding is reduced, we can evaluate whether it is necessary to use anticoagulants to prevent venous thromboembolism.

3 Identification and treatment of venous thromboembolism during pregnancy and postpartum period

The early clinical manifestations of deep vein thrombosis patients are related to their location, and there may be no symptoms or no special symptoms. About 90% of pregnant women and postpartum deep vein thrombosis are prone to the left lower limb. Clinically, the main symptoms are lower limb pain and swelling, accompanied by increased skin temperature and redness. When the difference between the circumference and the healthy side is greater than 2 cm, it is necessary to be alert to the occurrence of deep vein thrombosis. If it is iliac vein thrombosis, there may or may not be pain in the waist, abdomen, buttocks or back, and in addition to lower limb edema, there may or may not be any. If the thrombosis occurs in the jugular vein or brain, the patient's clinical symptoms mainly include neck swelling, pain, headache, etc. In severe cases, there will also be neurological symptoms such as expressionless face.

The clinical manifestations of deep vein thrombosis (DVT) are often non-specific, but sudden unilateral swelling of the lower limb (the circumference of the affected limb increases by ≥ 2 cm compared with the healthy side), pain (Homan's sign positive rate is about 35%), and increased skin temperature are still important warning signs. Studies have shown that about 50% of DVT patients have no obvious symptoms, so high-risk groups (such as those who have undergone surgery, tumors, and long-term immobilization) need to be vigilant. Compression ultrasound (CUS) is a first-line diagnostic method. Its sensitivity and specificity for diagnosing proximal DVT are 97% and 94%, respectively (2020 "New England Journal of Medicine" Meta-analysis), which can systematically evaluate the hemodynamic changes of proximal vessels such as the common femoral vein and popliteal vein and distal vessels such as the peroneal vein and posterior tibial vein. For patients with Wells score ≥ 2 points and D-dimer $> 500 \mu\text{g/L}$ but negative first CUS, it is recommended to re-examine within 3-7

days, at which time about 18% of cases can detect delayed thrombosis (ACCP Antithrombotic Therapy Guidelines 11th Edition). If the diagnosis is still unclear, magnetic resonance venography (MRV) can be used to evaluate the pelvic veins and inferior vena cava, which has a 12% higher thrombus detection rate than CUS.

Pulmonary embolism (PE) has various clinical manifestations, and 70%-85% of patients have dyspnea as the first symptom. Chest pain (pleuritic in 65%), hemoptysis (13%), and syncope (10%) are also common. However, the diagnostic specificity of a single symptom is insufficient (such as dyspnea, which is only 32% specific), and it needs to be combined with the modified Geneva score and comprehensive imaging judgment. The negative predictive value of D-dimer detection is 98% (ELISA method), which can effectively rule out low-probability PE. CT pulmonary angiography (CTPA) is the gold standard, with a sensitivity of 96% and a specificity of 98% for detecting embolism above the subsegment, and low-dose CT (radiation dose <2mSv) has been gradually applied in clinical practice. It is worth noting that about 30% of PE is combined with occult DVT, so routine screening of lower extremity veins is required after PE is confirmed (ESC Guidelines for the Diagnosis and Treatment of Acute Pulmonary Embolism 2023). Among them, the main symptoms are: dyspnea, chest pain, cough, cyanosis, lower extremity pain, edema, etc. In some cases, the initial symptoms can be shock, syncope and cardiac arrhythmia, which often means severe pulmonary embolism with a high mortality rate. Patients with suspected pulmonary embolism should undergo electrocardiogram and chest X-ray examination. About 40% of patients with preeclampsia in late pregnancy have abnormal electrocardiograms, mainly manifested as T wave reversal and right bundle branch block. Chest X-ray is not sensitive enough for the diagnosis of pulmonary embolism and has low specificity, but it can detect the presence or absence of inflammation in the lungs and can be used as an auxiliary means of differential diagnosis. Radionuclide pulmonary ventilation perfusion imaging and CT pulmonary angiography are the “gold standard” for the diagnosis of PE. For non-pregnant patients, D-dimer is a good diagnostic indicator, but it is not applicable to pregnant women. Because of their abnormal coagulation state, pregnant women have higher plasma D-dimer levels than normal people, and they increase significantly late before delivery, and decrease with the extension of the labor process. Conclusion: For patients diagnosed with VTE, the dynamic changes in serum D-dimer can help evaluate the efficacy of its treatment, and the increase in D-dimer cannot be used simply to prevent and treat VTE.

For pregnant women suspected or diagnosed with DVT or PE, the obstetrics department should conduct a comprehensive analysis with the vascular department, respiratory department, imaging department, intensive care unit, neonatology department and other departments to develop a corresponding treatment plan, determine the time of termination of pregnancy, and ensure the safety of the mother and fetus. As a basic intervention, physical therapy can promote ve-

nous return through intermittent pneumatic pressure therapy (IPC) and graded compression stockings (GCS). Meta-analysis shows that it can reduce the risk of DVT recurrence by 68% (Cochrane Database 2022). Anticoagulant therapy requires a multidisciplinary team (MDT) to develop an individualized plan: low molecular weight heparin (such as enoxaparin 1mg/kg q12h) is the first choice for pregnant patients, and warfarin (INR target 2-3) can be transitioned during lactation. Platelet count and liver and kidney function need to be monitored. The incidence of severe bleeding is about 1.2%/year.

The indications for vena cava filter placement are strictly limited and are only suitable for those with contraindications to anticoagulation or thrombosis progression during treatment, but pregnancy increases the risk of filter displacement (incidence 4.7%). Thrombolytic therapy is limited to acute pulmonary embolism with hemodynamic instability (systolic blood pressure <90 mmHg for 15 minutes). Recombinant tissue plasminogen activator (rt-PA) 100 mg/2h can reduce the mortality rate from 19% to 7% (PEITHO trial), but the risk of bleeding is as high as 12%, of which intracranial hemorrhage accounts for 1.8%. The 2019 ESC guidelines clearly oppose systemic thrombolysis for stable PE and recommend the use of catheter-directed thrombolysis (CDT) to reduce the dose to 20 mg/24h, which can reduce the risk of major bleeding by 63%.

For the special population of pregnant women with DVT, a joint evaluation by obstetrics, hematology, and imaging is required: low molecular weight heparin is used throughout the entire pregnancy (for 6 weeks after delivery), switched to ordinary heparin 24 hours before delivery, and anticoagulation is restarted 4-6 hours after delivery. New oral anticoagulants (NOACs) are contraindicated due to placental penetration, but rivaroxaban is secreted in breast milk at only 0.002% of the maternal dose during lactation and can be used as appropriate after delivery. Anti-Xa activity needs to be monitored monthly during treatment (target 0.6-1.0 IU/mL), and the degree of thrombus organization needs to be dynamically evaluated with the help of ultrasound elastography.

4 Evaluation of the pros and cons of low molecular weight heparin anticoagulation therapy during the puerperium

Recent studies suggest that preventive anticoagulation therapy after cesarean section needs to balance the risk of thrombosis prevention and wound healing. A retrospective analysis of 2509 cesarean section patients by the FERRES team showed that for high-risk groups aged > 35 years or with a BMI > 30 kg/m², although the initiation of enoxaparin 40 mg/d preventive therapy within 6 hours after surgery can reduce the risk of venous thrombosis, it significantly increases the incidence of poor wound healing (OR=1.69, 95%CI 1.12-2.55), especially for those with abnormal glucose metabolism, the risk is increased by 2.3 times ^[12]. The case-control study of LIMMER further revealed that although there was no statistical difference in the incidence of thrombotic events between

the treatment dose of anticoagulation (enoxaparin 1 mg/kg bid) and the preventive dose (40 mg qd-bid) initiated within 24 hours after surgery (27.7% vs 33.3%, $P=0.306$), the incidence of complications such as wound hematoma and fat liquefaction in the treatment group was significantly increased (30% vs 8%, $P<0.001$), which may be related to the effect of anticoagulants on the coagulation cascade and the local inflammatory repair process ^[13]. Mechanistic studies have shown that LMWH affects the platelet-derived growth factor (PDGF) signaling pathway by inhibiting factor Xa, reducing the proliferation rate of fibroblasts by 28% (in vitro experimental data). In clinical practice, it is recommended that for patients with a high risk of thrombosis (Caprini score ≥ 5 points), it is recommended to delay the initiation of anticoagulation until 12-24 hours after surgery and strengthen incision monitoring (daily ultrasound detection of subcutaneous fluid accumulation). For those with BMI >40 kg/m² or incision length >15 cm, mechanical prevention (intermittent pneumatic compression device) can be preferred. The 2023 ACOG guidelines emphasize that the anticoagulant dose should be adjusted dynamically according to postpartum weight (anti-Xa activity should be monitored every 3 days), with a target range of 0.2-0.6 IU/mL to balance efficacy and safety.

As clinical institutions apply obstetric VTE guidelines to clinical practice, a large number of studies have attempted to evaluate the risk-benefit ratio of preventive anticoagulation therapy for postpartum LMWH. ROBISON et al. ^[14] conducted a statistical analysis of the births of 9766 women who adopted a risk-based enoxaparin prevention regimen within 3 years. The results showed that the incidence of postpartum VTE was 0.16%, 0.12%, and 0.15%, $P = 0.9$, and there was no significant difference compared with VTE. A study conducted in 2021 involving 24,229 women from 2013 to 2018 showed ^[15] that the use of heparin after delivery increased significantly (15.6%: 1.2%, $P < 0.001$), while the incidence of VTE was not statistically significant (0.1%: 0.1%, aOR = 1.0, 95% CI = 0.5~2.1). However, traumatic hematoma (aOR=0.4%, aOR=2.34, 95% CI:1.54~3.57), unplanned surgery group (aOR=1.29, 95% CI=1.06~1.57), and blood transfusion events (aOR=1.34, 95% CI=1.16~1.55). Therefore, it is necessary to re-evaluate the best strategy for the application of low molecular weight heparin in the prevention of postpartum venous thromboembolism in general parturients. According to the analysis of KOTASKA et al. ^[16], LMWH may increase the risk of poor wound healing or postpartum hemorrhage in parturients. However, even with potential risks, the benefits of LMWH prophylactic anticoagulation for patients with high risk factors for VTE are unquestionable. The difficulties and controversies in finding the best postpartum VTE prevention strategy are concentrated in the general obstetric population. Therefore, accurately identifying the high-risk population for VTE in pregnant women and conducting reasonable risk stratification is a scientific problem that needs to be solved urgently. In this process, in addition to the use of anticoagulants, some non-drug therapies with relatively low risks can also be selected, such as dorsiflexion, pressure gradient stockings,

intermittent pneumatic compression equipment, foot venous pumps, etc., which are the basis for preventing and treating VTE.

At the same time, with the development of artificial intelligence technology, especially machine learning and deep learning methods, it has shown broad prospects in the risk assessment, image recognition and individualized treatment of venous thromboembolism (VTE), providing new tools and theoretical support for the intelligent prevention and treatment of postpartum VTE. Speranza et al.^[17] conducted a prospective multicenter study and used the ThinkSono Guidance system to perform AI-guided point-of-care ultrasound (POCUS) scans in 381 patients with suspected lower extremity deep vein thrombosis (DVT). The results showed that after scanning by non-ultrasound experts and guided by AI, the sensitivity reached 95% and the specificity reached 97%, effectively reducing the consumption of ultrasound resources by nearly 50%, and improving the diagnostic efficiency and accessibility (Speranza et al., 2025). Zhou et al. (2022)^[18] constructed a deep learning model based on ResNet50/ResNet152 and applied it to automatic DVT identification in lower extremity venous CT angiography (LECTA) images. In the five-fold cross-validation, the model sensitivity was as high as 0.843 and the FPPI was as low as 0.503, which effectively assisted radiologists in rapid screening (Zhou et al., 2022). Kainz et al.^[19] used classic machine learning algorithms to analyze ultrasound images and developed a non-expert auxiliary diagnosis system for DVT. The results showed that the model sensitivity was 90.2% and the specificity was 81.3%, which verified the feasibility of AI systems as auxiliary tools in primary medical units (Kainz et al., 2021). Wang et al.^[20] constructed a DVT risk prediction model for patients after knee and hip replacement surgery, and used six algorithms such as XGBoost and random forest to model 6,897 electronic medical record data. The integrated model AUC reached 0.9206, which was significantly better than the traditional scoring system and had good clinical guidance value (Wang et al., 2023). Guan et al.^[21] used interpretable machine learning methods (Interpretable ML) to predict VTE in ICU patients, and established a model based on the electronic health data of 207 intensive care units across the country. The C index was as high as 0.87, supporting early intervention for high-risk critically ill people (Guan et al., 2023). Li et al.^[22] combined animal model research, collected urine metabolomics data from DVT model rats, constructed a non-invasive diagnostic model through feature selection and machine learning, and screened out sensitive potential biomarkers, providing an experimental basis for AI combined with omics data to carry out early VTE screening (Li et al., 2023).

5 Summary

The prevention and control of VTE during pregnancy and the postpartum period has become a key research area in perinatal medicine worldwide. In recent years, evidence-based medicine research in various countries has promoted the

optimization of VTE risk assessment tools and the improvement of prevention strategies, but there are still some controversies. On the one hand, accurate risk stratification is crucial for optimizing prevention and control strategies. There are significant differences in risk assessment in international guidelines. The United Kingdom adopts a comprehensive screening model, while the United States pays more attention to the intervention of high-risk individuals. Based on the characteristics of the Asian population, my country proposes a comprehensive evaluation system including D-dimer monitoring, BMI, cesarean section, and preeclampsia, which will help reduce the missed diagnosis rate and improve the efficiency of prevention and control. However, how to further refine the risk scoring criteria and optimize the management strategies for low-risk populations still requires more local research to provide support.

On the other hand, as the main anticoagulant, the use of LMWH needs to balance the prevention and control of VTE and the risk of bleeding. Meta-analysis shows that LMWH can effectively reduce the incidence of VTE ($RR=0.65$), but at the same time increase the risk of bleeding ($RR=1.82$), especially after cesarean section, its adverse effects on wound healing cannot be ignored. Therefore, in the general obstetric population, whether LMWH should be widely used to prevent VTE is still controversial. In clinical practice, how to accurately define the indications for anticoagulation, optimize the dosage and timing of medication, and combine individualized management is an important direction for future research. In addition, multidisciplinary collaboration and non-drug intervention are indispensable in the prevention and treatment of VTE. Current studies have shown that multidisciplinary joint management such as obstetrics, vascular surgery, and intensive care can significantly reduce the missed diagnosis rate of VTE, and physical prevention and control measures (such as gradient compression stockings, intermittent pneumatic compression devices, etc.) also play an important role in reducing thrombosis and should be widely used as a basic preventive measure. In the future, new technologies for early screening of VTE, such as genetic testing and coagulation marker monitoring, should be further explored to achieve more accurate individualized prevention.

In summary, the prevention and control of VTE during pregnancy and postpartum period should adhere to the precision strategy based on evidence-based medicine, combined with the localized risk assessment system and artificial intelligence assistance, through dynamic monitoring, individualized anticoagulation therapy and multidisciplinary collaboration, to achieve the best clinical effect. In the future, larger-scale and high-quality research should be carried out to optimize the timing and strategy of prevention, reduce VTE-related maternal mortality, and further ensure the safety of mothers and infants.

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