

Original Research

Diagnostic Value of Combined Late-Pregnancy Measurements of Fasting Plasma Glucose, D-Dimer, High-Density Lipoprotein, and Low-Density Lipoprotein for Diagnosing Puerperal Venous Thromboembolism

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Abstract

Background: To investigate the diagnostic value of late-pregnancy measurements of fasting plasma glucose (FPG), D-dimer (D-D), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) for postpartum venous thromboembolism (VTE). **Methods:** A retrospective analysis was conducted on the clinical data of 203 postpartum women admitted to our hospital from January 2021 to June 2023. Based on the occurrence of VTE, they were categorized into a VTE group ($n = 103$) and a non-VTE group ($n = 100$). Univariate analysis and multivariate logistic regression were used to identify related factors. Pearson correlation analysis was conducted, and receiver operating characteristic (ROC) curves were applied to evaluate the diagnostic performance of individual and combined biomarkers. **Results:** No significant differences were observed between the two groups with respect to gestational age, gravidity, preeclampsia, gestational hypertension, fibrinogen (FIB), activated partial thromboplastin time (APTT), prothrombin time (PT), total cholesterol (TC), or triglycerides (TG) ($p > 0.05$). The VTE group presented with higher proportions of women aged ≥ 35 years, obesity, postpartum hemorrhage, gestational diabetes mellitus, and cesarean section, as well as higher Royal College of Obstetricians and Gynaecologists (RCOG) scores, levels of FPG, D-D, and LDL, compared with the non-VTE group. High-density lipoprotein (HDL) levels were significantly lower in the VTE group than in the non-VTE group ($p < 0.05$). Pearson correlation analysis showed that FPG, D-D, and LDL were positively correlated with the RCOG score, whereas HDL was negatively correlated with the RCOG score ($p < 0.05$). Multivariate logistic regression analysis indicated that age ≥ 35 years, obesity, postpartum hemorrhage, cesarean section, gestational diabetes mellitus, RCOG score, FPG, D-D, HDL, and LDL were independent influencing factors for postpartum VTE ($p < 0.05$). ROC curve analysis demonstrated that the combined detection of the four biomarkers had significantly higher area under the curve (AUC) and sensitivity than individual indicators ($p < 0.05$). **Conclusion:** The combined detection of FPG, D-D, HDL, and LDL demonstrates high sensitivity for diagnosing postpartum VTE and may be used for early diagnosis and prevention.

Keywords: fasting plasma glucose; D-dimer; high-density lipoprotein; low-density lipoprotein; postpartum venous thrombosis

1. Introduction

Venous thromboembolism (VTE), encompassing deep vein thrombosis (DVT) and pulmonary embolism (PE), refers to abnormal blood coagulation within the venous system, leading to vascular obstruction and impaired venous return [1]. Due to physiological changes such as a hypercoagulable state, vascular injury, and venous stasis, pregnant and postpartum women face a substantially elevated risk of VTE—approximately five to ten times higher than that of non-pregnant women [2]. Once VTE occurs, detached thrombi may migrate to the pulmonary circulation, resulting in pulmonary embolism, adversely affecting breastfeeding and postpartum recovery, and in severe cases, may lead to maternal death [3]. Therefore, early diagnosis and prevention of VTE in pregnant and postpartum women are of paramount importance.

Given their unique physiological status, women during pregnancy and the postpartum period often exhibit hypercoagulability and dysregulated lipid metabolism, and may develop complications such as gestational diabetes mellitus or hypertensive disorders of pregnancy. These factors are all strongly associated with the development of VTE in this patient population [4,5]. To investigate the clinical value of combined measurement of fasting plasma glucose (FPG), D-dimer (D-D), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) in the diagnosis of puerperal VTE, we conducted a retrospective analysis of clinical data from 203 postpartum women admitted to our hospital. The findings are presented below.



2. Materials and Methods

2.1 General Information

A retrospective analysis was conducted on the clinical data of 203 postpartum women admitted to our hospital from January 2021 to June 2023. Based on the occurrence of VTE, they were categorized into a VTE group ($n = 103$) and a non-VTE group ($n = 100$), as detailed in Fig. 1. Inclusion criteria: All patients were diagnosed by imaging modalities, including color Doppler ultrasound of the lower extremities and CT pulmonary angiography, clinical manifestations included unilateral lower extremity swelling, pain, dyspnea, and chest pain; patients in the VTE group met the diagnostic criteria outlined in the Expert Consensus on the Prevention and Management of Venous Thromboembolism During Pregnancy and the Postpartum Period [6]; newly diagnosed venous thromboembolism (VTE), including deep vein thrombosis (DVT) and/or pulmonary embolism (PE), occurring within 6 weeks postpartum (i.e. within 42 days postpartum) after delivery of the fetus, will not be included in this study if VTE occurs during pregnancy, before delivery, or after 6 weeks postpartum, all women had singleton pregnancies with cephalic presentation, underwent regular prenatal examinations, delivered in our hospital, and had complete clinical data; all participants were age ≥ 18 years. Exclusion criteria: VTE attributed to other causes; antithrombotic or antiplatelet therapy (including aspirin) before enrollment; severe cardiac, hepatic, or renal impairment; hematological or immune system disorders; malignancies; infectious diseases. In the VTE group, age ranged from 21 to 39 years (mean 28.36 ± 4.72 years), and thrombus locations included lower extremity DVT (89 cases), pulmonary embolism (5 cases), and DVT combined with pulmonary embolism (9 cases). In the non-VTE group, age ranged from 22 to 38 years (mean 28.12 ± 4.93 years). Patients hospitalized during the same period without VTE served as the non-VTE group. This study was approved by the Medical Ethics Committee of Qinhuangdao Maternal and Child Health Hospital (QHDFY-2024061112).

2.2 Examination Methods

(1) Clinical data collected included age, gestational age, pre-pregnancy body mass index ($BMI = kg/m^2$), gravidity, preeclampsia, gestational hypertension, postpartum hemorrhage, cesarean section rate, and the Royal College of Obstetricians and Gynaecologists (RCOG) risk score.

(2) A 6 mL fasting venous blood sample was collected from all participants in the early morning during late pregnancy (≥ 28 weeks). D-dimer (D-D), fibrinogen (FIB), prothrombin time (PT), and activated partial thromboplastin time (APTT) were measured using a Sysmex CA1500 automated coagulation analyzer (Sysmex Corporation, Kobe, Japan). Fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) were measured using an Abbott ARCHITECT c16000 automatic biochemical ana-

lyzer (Abbott Laboratories, Abbott Park, IL, USA) with matching reagents. The diagnostic cut-off values for the individual biomarkers were defined as follows:

FPG > 5.19 mmol/L, D-dimer > 536.47 $\mu g/L$, HDL < 0.93 mmol/L, and LDL > 2.71 mmol/L.

For the combined (parallel) testing approach, a positive result in any one of these indicators was considered a positive screening result.

2.3 Evaluation Indicators

Color Doppler ultrasound of the lower extremities served as the gold standard for the diagnosis of deep vein thrombosis (DVT), while CT pulmonary angiography (CTPA) was used for the diagnosis of pulmonary embolism (PE). Clinical indicators were compared between the two groups, and risk factors for postpartum VTE were analyzed. The diagnostic performance of individual and combined predictors was evaluated. The RCOG scoring system (Qinhuangdao, Hebei, China) includes 27 risk factors, each assigned a score; total scores classify patients as low risk (0–1), moderate risk (2), or high risk (≥ 3). Sensitivity = true positives / (true positives + false negatives) $\times 100\%$; specificity = true negatives / (true negatives + false positives) $\times 100\%$; Youden index = sensitivity + specificity – 1.

2.4 Statistical Analysis

SPSS 23.0 (IBM Corp., Armonk, NY, USA) was used for data analysis. Categorical variables were compared using the chi-square test, while for continuous variables, the Shapiro-Wilk test was first used to assess normality; all data followed a normal distribution, and the t -test was used for comparison. Pearson correlation analysis was conducted. Univariate and multivariate logistic regression analyses were used to identify risk factors. Receiver operating characteristic (ROC) curves and the area under the curve (AUC) were used to assess diagnostic performance. Pairwise comparisons of AUC values were conducted using the Z-test. Sensitivity and specificity were calculated, and McNemar's test (paired chi-square test) was used for comparisons. A parallel testing strategy was adopted, whereby a positive result was defined as a positive finding in any single indicator. A p value < 0.05 was considered statistically significant.

3. Results

3.1 Comparison of Baseline Characteristics Between the Two Groups

No statistically significant differences were observed between the two groups with respect to gestational age, gravidity, preeclampsia, gestational hypertension, fibrinogen (FIB), activated partial thromboplastin time (APTT), prothrombin time (PT), total cholesterol (TC), or triglycerides (TG) ($p > 0.05$). The VTE group presented with higher proportions of women aged ≥ 35 years, obesity, postpartum hemorrhage, gestational diabetes mellitus, and ce-

Table 1. Comparison of baseline characteristics between the two groups of postpartum women.

Clinical data	VTE group (n = 103)	Non-VTE group (n = 100)	χ^2/t	<i>p</i>
Age (years)			12.059	<0.001
≥35 years	24 (23.3)	6 (6.0)		
<35 years	79 (76.7)	94 (94.0)		
Gestational age (weeks)			0.420	0.517
≥37 weeks	98 (95.1)	93 (93.0)		
<37 weeks	5 (4.9)	7 (7.0)		
Obesity (pre-pregnancy BMI ≥30 kg/m ²)			12.236	<0.001
Yes	29 (28.2)	9 (9.0)		
No	74 (71.8)	91 (91.0)		
Gravidity			1.343	0.247
≥2 Times	41 (39.8)	32 (32.0)		
<2 Times	62 (60.2)	68 (68.0)		
Assisted reproduction			2.254	0.133
Yes	11 (10.7)	5 (5.0)		
No	92 (89.3)	95 (95.0)		
Postpartum hemorrhage			9.468	0.002
Yes	23 (22.3)	7 (7.0)		
No	80 (77.7)	93 (93.0)		
Preeclampsia			2.102	0.147
Yes	20 (19.4)	12 (12.0)		
No	83 (80.6)	88 (88.0)		
Gestational hypertension			2.485	0.115
Yes	22 (21.4)	13 (13.0)		
No	81 (78.6)	87 (87.0)		
Gestational diabetes mellitus			17.106	<0.001
Yes	41 (39.8)	14 (14.0)		
No	62 (60.2)	86 (86.0)		
Mode of delivery			9.282	0.002
Cesarean section	58 (56.3)	35 (35.0)		
Vaginal delivery	45 (43.7)	65 (65.0)		
RCOG score	3.24 ± 0.94	1.47 ± 0.97	13.203	<0.001
FPG (mmol/L)	6.34 ± 1.24	4.67 ± 1.15	9.942	<0.001
D-D (μg/L)	943.26 ± 214.75	362.18 ± 185.49	20.606	<0.001
FIB (g/L)	3.01 ± 0.63	2.94 ± 0.66	0.773	0.440
APTT (s)	27.35 ± 4.62	28.16 ± 4.85	1.219	0.224
PT (s)	14.16 ± 4.38	15.13 ± 4.53	1.551	0.122
TC (mmol/L)	4.47 ± 1.38	4.21 ± 1.45	1.309	0.192
TG (mmol/L)	1.15 ± 0.64	1.06 ± 0.42	1.181	0.239
HDL (mmol/L)	0.87 ± 0.17	1.32 ± 0.19	17.795	<0.001
LDL (mmol/L)	2.96 ± 0.74	1.88 ± 0.53	11.924	<0.001

VTE, venous thromboembolism; BMI, body mass index; RCOG, Royal College of Obstetricians and Gynaecologists; FPG, fasting plasma glucose; D-D, D-dimer; FIB, fibrinogen; APTT, activated partial thromboplastin time; PT, prothrombin time; TC, total cholesterol; TG, triglycerides; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

sarean section, as well as higher RCOG scores and levels of fasting plasma glucose (FPG), D-dimer (D-D), and low-density lipoprotein (LDL), compared with the non-VTE group. High-density lipoprotein (HDL) levels were significantly lower in the VTE group than in the non-VTE group ($p < 0.05$), as detailed in Table 1.

3.2 Correlation Between FPG, D-D, HDL, LDL Levels and RCOG Scores in Postpartum Women With VTE

Pearson correlation analysis showed that FPG, D-D, and LDL were positively correlated with the RCOG score in postpartum women with VTE ($p < 0.05$), whereas HDL was negatively correlated with the RCOG score ($p < 0.05$), as detailed in Table 2.

Table 2. Correlation between FPG, D-D, HDL, LDL levels and RCOG scores in postpartum women with VTE.

Influencing factors	R-value	p-value
FPG	0.623	<0.001
D-D	0.607	<0.001
HDL	-0.618	<0.001
LDL	0.654	<0.001

3.3 Multivariate Logistic Regression Analysis of Factors Associated With Postpartum VTE

A multivariate logistic regression analysis was performed with postpartum VTE occurrence (non-occurrence = 0, occurrence = 1) as the dependent variable, and age ≥ 35 years, obesity, postpartum hemorrhage, gestational diabetes mellitus, cesarean section, RCOG score, FPG, D-D, HDL, and LDL as independent variables. The results showed that age ≥ 35 years, obesity, postpartum hemorrhage, gestational diabetes mellitus, cesarean section, RCOG score, FPG, D-D, HDL, and LDL were independent influencing factors for the occurrence of postpartum VTE ($p < 0.05$), as detailed in Tables 3,4.

Table 3. Assignment instructions for multivariate analysis.

Variable	Variable Description
Age ≥ 35 years	No = 0, Yes = 1
Obesity	No = 0, Yes = 1
Gestational diabetes	No = 0, Yes = 1
Cesarean section	No = 0, Yes = 1
Postpartum hemorrhage	No = 0, Yes = 1
RCOG score	Actual value
FPG	Actual value
D-D	Actual value
HDL	Actual value
LDL	Actual value

3.4 Diagnostic Value of Combined Detection of FPG, D-D, HDL and LDL for Postpartum VTE

We used binary logistic regression to construct a joint diagnostic model and obtained the regression equation: $\text{Logit}(P) = -5.112 + 0.682 \times \text{FPG} + 0.493 \times \text{D-D} - 0.575 \times \text{HDL} + 0.462 \times \text{LDL}$. We calculated the prediction probability and plotted the ROC curve based on the predicted probability. The ROC curve showed that the AUC and sensitivity of the combined detection using the four indicators for diagnosing postpartum VTE were 0.966 and 96.1%, respectively. The AUC and sensitivity of the combined detection were significantly higher than those of each individual indicator, indicating high diagnostic value ($p < 0.05$), as shown in Table 5 and Fig. 2.

4. Discussion

During pregnancy, women undergo significant physiological changes, including hemodynamic alterations, elevated estrogen levels, a hypercoagulable state, and vascular injury. These factors predispose pregnant women to thrombotic diseases, rendering them a high-risk population for VTE. Clinically, VTE may present with limb swelling, abdominal pain, back pain, or other symptoms [7,8]. However, similar symptoms may also occur in otherwise healthy postpartum women, making the clinical diagnosis of pregnancy-related VTE challenging.

Elevated blood glucose levels in pregnant and postpartum women can lead to pathological changes, including decreased anticoagulant proteins and increased blood viscosity. These changes also promote vascular endothelial dysfunction and platelet activation, thereby contributing to an increased risk of thrombosis [9]. Research by Orrin et al. [10] has shown that gestational diabetes mellitus is a significant risk factor for VTE in late pregnancy.

D-dimer (D-D) is a fibrin degradation product that remains stable under normal physiological conditions. Elevated D-D levels directly indicate a hypercoagulable state and secondary fibrinolytic activation [11]. Therefore, D-D is commonly used in clinical practice as an indicator to rule out VTE. Studies have demonstrated that D-D has high diagnostic value for predicting VTE in pregnant and postpartum women [12]. Another study found that D-D levels during pregnancy and the postpartum period were significantly higher than those in healthy women, with the highest level observed at 24 hours postpartum ($p < 0.05$). In 10 women who developed postpartum VTE, D-D levels measured in late pregnancy, at 24 hours, and at 72 hours postpartum were all significantly higher than those in women without VTE ($p < 0.05$). Moreover, D-D measured at 24 hours postpartum had the highest predictive value, with a sensitivity of 69.4%, a specificity of 76.8%, and an AUC of 0.74 [13].

High-density lipoprotein (HDL), which is primarily synthesized in the liver and small intestine, is responsible for transporting total cholesterol (TC) and triglycerides (TG) [14]. HDL is closely associated with VTE formation. HDL exerts antithrombotic effects by promoting the synthesis of nitric oxide (NO) and prostacyclin, regulating thromboxane A2 and platelet-activating factor levels, and thereby inhibiting platelet aggregation. Additionally, HDL can activate the guanylate cyclase system, reduce circulating von Willebrand factor, and attenuate platelet adhesion and aggregation [15]. Low-density lipoprotein (LDL), a cholesterol-rich lipoprotein, can undergo oxidation to form oxidized LDL (ox-LDL) within tissues and is considered one of the key factors contributing to the development of VTE [16]. LDL can induce endothelial injury, stimulate smooth muscle cell proliferation, and promote the transformation of lipids into foam cells, ultimately contributing to thrombosis. By affecting leukocyte and platelet function,

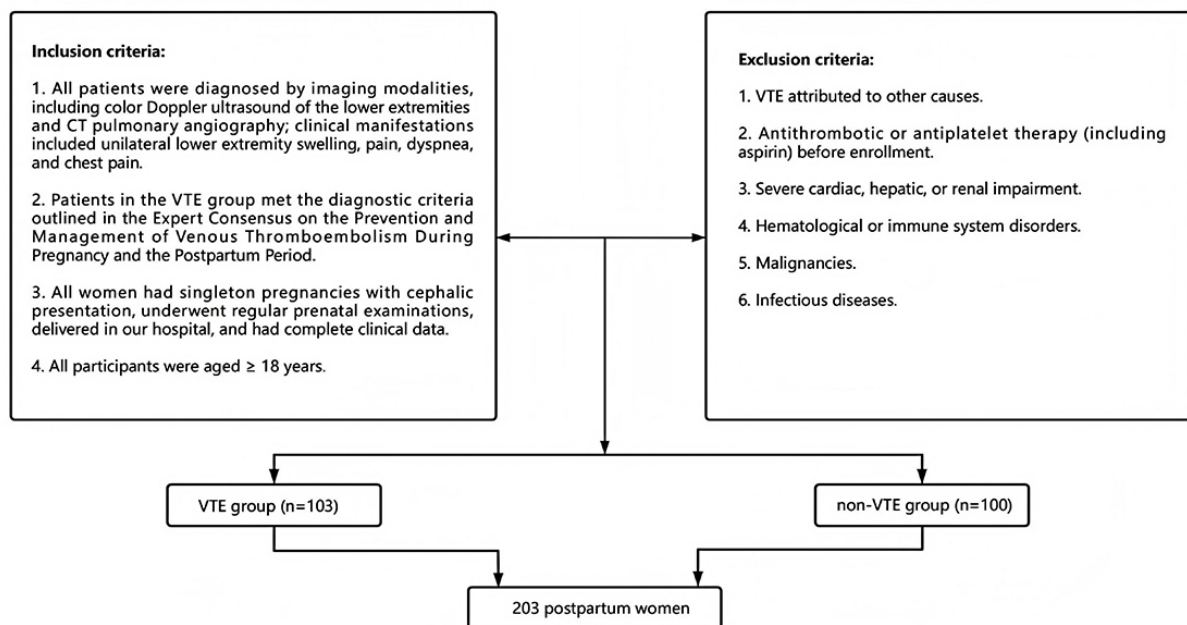
Table 4. Multivariate logistic regression analysis of postpartum VTE in women.

Influencing factors	β	SE	Wald χ^2	p	OR	95% CI
Age ≥ 35 years	0.472	0.142	11.049	0.001	1.603	1.214~2.118
Obesity	0.562	0.127	19.582	<0.001	1.754	1.368~2.250
Gestational diabetes mellitus	0.403	0.139	8.406	0.004	1.496	1.139~1.965
Cesarean section	0.368	0.113	10.606	0.001	1.445	1.158~1.803
Postpartum hemorrhage	0.329	0.108	9.280	0.002	1.390	1.124~1.717
RCOG score	1.884	0.627	9.029	0.003	6.580	1.925~22.487
FPG	0.734	0.217	11.441	0.001	2.083	1.362~3.188
D-D	0.543	0.125	18.870	<0.001	1.721	1.347~2.199
HDL	-0.615	0.146	17.744	<0.001	0.541	0.406~0.720
LDL	0.504	0.165	9.330	0.002	1.655	1.198~2.287

Table 5. Diagnostic value of combined detection of FPG, D-D, HDL and LDL for postpartum VTE.

Index	Optimal cutoff	AUC	Standard error	p	95% CI	Sensitivity (%)	Specificity (%)
FPG	5.19 mmol/L	0.873	0.024	<0.001	0.820~0.915	84.5	76.0
D-D	536.47 $\mu\text{g/L}$	0.904	0.026	<0.001	0.853~0.955	90.3	75.0
HDL	0.93 mmol/L	0.856	0.027	<0.001	0.801~0.912	75.7	84.0
LDL	2.71 mmol/L	0.829	0.045	<0.001	0.741~0.918	73.8	81.0
Combined		0.912	0.014	<0.001	0.911~0.966	96.1	71.0

AUC, area under the curve; CI, confidence interval.

**Fig. 1. Flowchart of patient selection and grouping in the study population.**

LDL accelerates coagulation, inhibits fibrinolytic activity, damages endothelial cells, enhances cellular adhesion, and thereby contributes to VTE formation [17]. One study reported that patients with lower-extremity DVT had elevated serum LDL and reduced HDL levels, and that coagulation factors FIB and D-D played a role in monitoring DVT development. Changes in serum LDL and HDL were closely associated with alterations in FIB and D-D levels, suggesting strong interactions between lipid profiles and coagula-

tion indicators in the progression of lower-extremity DVT [18,19].

The results of this study showed that there were no statistically significant differences between the two groups in gestational age, gravidity, preeclampsia, gestational hypertension, FIB, APTT, PT, TC, or TG ($p > 0.05$). The proportions of women aged ≥ 35 years, obesity, postpartum hemorrhage, gestational diabetes mellitus, and cesarean section, as well as the levels of RCOG score, FPG, D-D, and LDL,

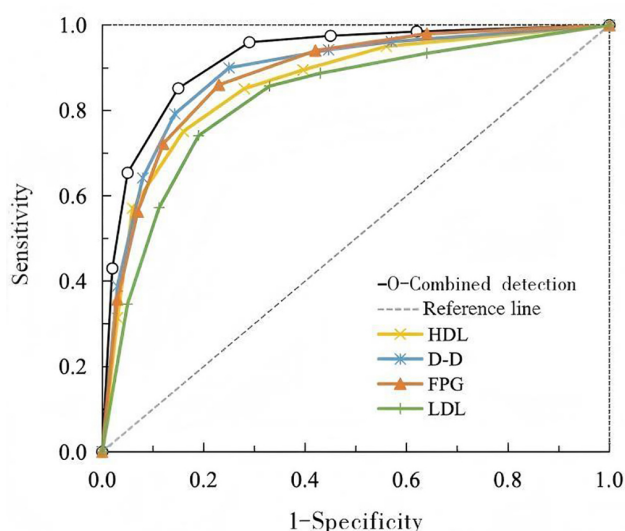


Fig. 2. ROC curve analysis of the five indicators for postpartum VTE. ROC, receiver operating characteristic.

were higher in the VTE group than in the non-VTE group, whereas HDL levels were lower in the VTE group ($p < 0.05$). These findings suggest that multiple factors contribute to the development of postpartum VTE, and a comprehensive assessment based on clinical symptoms and biochemical indicators is necessary. This study also indicated that, based on Pearson correlation analysis, FPG, D-D, and LDL were positively correlated with RCOG scores in postpartum women with VTE ($p < 0.05$), while HDL was negatively correlated with RCOG scores ($p < 0.05$). The RCOG score is a commonly used risk assessment tool for thrombotic events during pregnancy and the postpartum period, incorporating multiple risk factors such as advanced maternal age, obesity, cesarean section, and postpartum hemorrhage [20]. These findings further support the close association of FPG, D-D, LDL, and HDL with postpartum VTE.

In addition, the results of the multivariate logistic regression analysis showed that age ≥ 35 years, obesity, postpartum hemorrhage, gestational diabetes mellitus, cesarean section, RCOG score, FPG, D-D, HDL, and LDL were independent influencing factors for postpartum VTE ($p < 0.05$). Possible explanations are as follows: First, advanced maternal age is associated with endothelial injury and increased procoagulant substances, while slower postpartum recovery further increases the risk of thrombosis. Second, obese women have a higher body mass index and greater venous pressure, leading to reduced blood flow velocity, increased venous injury, and a higher likelihood of VTE. Third, postpartum hemorrhage activates coagulation pathways to reduce blood loss, which simultaneously increases the risk of thrombosis. Fourth, cesarean delivery may cause pelvic venous endothelial injury, impair venous return from the lower extremities, and activate coagulation during surgical manipulation, thereby increasing VTE risk. Postoperative bed rest further reduces lower limb movement and im-

pairs circulation, promoting venous stasis and thrombosis. Moreover, hyperglycemia, hypercoagulability, and dyslipidemia are common contributors to VTE in pregnant and postpartum women. Hyperglycemia increases blood viscosity, impairs endothelial function, and promotes platelet activation. Elevated plasma D-dimer levels indicate a hypercoagulable state and suggest thrombus formation. HDL and LDL participate in VTE development through multiple pathways, playing important roles in thrombogenesis. Conversely, TC and TG were not associated with VTE, likely because VTE is primarily driven by platelet aggregation, and platelets do not express receptors for TC or TG; therefore, these lipids do not directly promote platelet aggregation or VTE.

ROC curve analysis in this study demonstrated that the combined detection of FPG, D-D, HDL, and LDL achieved significantly higher AUC and sensitivity compared with those of each individual indicator ($p < 0.05$). This suggests that combining blood glucose, coagulation markers, and lipid indicators offers high predictive value for postpartum VTE and can be applied in screening and diagnosis in pregnant and postpartum women. These tests are simple and efficient, and measuring these indicators can facilitate early identification of a prethrombotic state or secondary hyperfibrinolysis in postpartum women, enabling timely prediction of VTE risk and early intervention, thereby reducing the occurrence of VTE and improving maternal recovery. Although combined detection has high diagnostic value, some false positives and false negatives may still occur. Therefore, in clinical practice, imaging modalities such as color Doppler ultrasonography, magnetic resonance imaging, or spiral CT should be integrated for comprehensive evaluation, as this approach can significantly improve diagnostic accuracy and help avoid missed or incorrect diagnoses.

Limitations

This was a single-center retrospective study with a limited sample size, which may have introduced selection bias. The cutoff value for the combined detection was derived from our own dataset and has not been externally validated. In addition, the imaging modalities varied across patients, potentially affecting the consistency of the reference standard. Future multicenter prospective studies are warranted to further validate the diagnostic value of these indicators.

5. Conclusion

The combined detection of FPG, D-D, HDL, and LDL demonstrates high sensitivity for diagnosing postpartum VTE and may be used for early diagnosis.

Abbreviations

APTT, activated partial thromboplastin time; AUC, area under the curve; BMI, body mass index; CTPA, CT

pulmonary angiography; D-D, D-dimer; DVT, deep vein thrombosis; FIB, fibrinogen; FPG, fasting plasma glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; NO, nitric oxide; ox-LDL, oxidized LDL; PE, pulmonary embolism; PT, prothrombin time; RCOG, Royal College of Obstetricians and Gynaecologists; ROC, receiver operating characteristic; TC, total cholesterol; TG, triglycerides; VTE, venous thromboembolism.

Availability of Data and Materials

The original data presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Author Contributions

FX: Proposed the main research objectives, conceptualized and designed the study, implemented the research, drafted the manuscript, supervised quality control, and reviewed the article, taking overall responsibility for the manuscript; LZ: Drafted the manuscript or revised it critically for important intellectual content; collected and organized data, performed statistical analysis, and created and presented figures and tables; JS: Revised the manuscript, the acquisition, analysis, or interpretation of data for the work. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki, and the protocol was approved by the Medical Ethics Committee of Qinhuangdao Maternal and Child Health Hospital (QHDFY-2024061112). All patients or their families/legal guardians gave their informed consent for inclusion before they participated in the study.

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Conflicts of Interest

The authors declare no conflicts of interest.

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