Clin. Lab. 2026;72:XXX-XXX

ORIGINAL ARTICLE

Deep Vein Thrombosis in Pelvic Tumor Patients: Correlating Serum Coagulation Factors with Clinical Risk Profiles

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SUMMARY

Background: **This study aimed to investigate the clinical features, coagulation, and risk factors of deep vein thrombosis (DVT) in patients with pelvic tumor and to construct a prediction model for postoperative DVT events.**
Methods: **Clinical data of 161 patients with pelvic tumors (preoperative DVT group n = 22, non-DVT group n = 139; postoperative DVT group n = 35, NDVT group n = 125; and one case of postoperative pulmonary thrombosis was excluded) were retrospectively analyzed. Age, BMI, disease type, FIGO stage, and coagulation parameters (prothrombin time, PT; activated partial thromboplastin time, APTT; fibrinogen, FIB; D-dimer, D-D; plasminogen activator inhibitor-1, PAI-1) were compared. The key variables were screened using principal component analysis. The prediction model for postoperative DVT was built through logistic regression, and its efficacy was tested using a ROC curve.**
Results: **PT, D-D, and PAI-1 were significantly higher in the preoperative DVT group than in the non-DVT group ($p < 0.001$), and APTT was significantly shorter ($p = 0.002$). The postoperative DVT group was characterized by advanced age ($p = 0.032$), a higher proportion of ovarian and endometrial cancers, a greater percentage of advanced FIGO stages ($p = 0.002$), longer postoperative bedtime of more than 72 hours ($p = 0.028$), and higher levels of PT, FIB, D-D, and PAI-1 ($p < 0.001$). Principal component analysis showed age and D-D as the main contributing factors. The logistic regression model showed that age (OR = 1.02, $p = 0.05$), elevated D-D (OR = 1.02, $p = 0.001$), FIGO stages III and IV (OR = 3.60, $p = 0.048$), absence of thrombolytic prophylaxis in the postoperative period (OR = 2.85, $p = 0.049$), and the presence of adjuvant therapy in the postoperative period (OR = 1.02, $p = 0.038$) were independent risk factors for postoperative DVT, and the AUC of the model reached 0.865 ($p < 0.001$).**
Conclusions: **Age, preoperative DVT, D-D level, and tumor stage are independent predictors of postoperative DVT in pelvic tumors. The constructed prediction model has high clinical value.**
(Clin. Lab. 2026;72:xx-xx. DOI: 10.7754/Clin.Lab.2025.250324)

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Manuscript accepted May 3, 2025

KEYWORDS

deep vein thrombosis, pelvic tumor, coagulation index, prediction model, logistic regression, principal component analysis

INTRODUCTION

In the postoperative phase, patients with pelvic tumors often encounter the significant issue of deep vein thrombosis (DVT), a frequent complication with an occurrence rate ranging from 19.6% to 38.0% [1,2]. DVT may not only trigger extreme life-threatening situations such as pulmonary embolism, but it also profoundly affects the quality of daily life and the overall recovery process of patients in the long run. In view of this, an in-depth investigation of the potential risk factors for DVT in pelvic tumors is of great importance for the development of effective prevention strategies and treatment plans.

The risk of DVT in patients with pelvic tumors is rooted in a complex interplay of several factors, with the direct intervention of surgical operations, prolonged postoperative bedtime, the hypercoagulable state of the tumor itself, and the unique individual characteristics of the patient all playing key roles [3-5]. Of particular interest, blood hypercoagulation is regarded as the central pathologic mechanism of DVT [6]. By releasing a series of procoagulant substances, tumor cells activate the coagulation system in the body and simultaneously inhibit the normal function of the fibrinolytic system, leading to an abnormal tendency for the blood to become hypercoagulable, which greatly increases the risk of thrombosis [6,7]. Unavoidable mechanical damage during pelvic surgery and extended bed rest for rehabilitation can further obstruct venous blood flow and damage the venous wall [8,9].

It is well known that the role of serum coagulation factors in the process of thrombosis, such as fibrinogen (FIB), D-dimer (D-D), and activated partial thromboplastin time (APPT), has been widely demonstrated to be inextricably linked to thrombosis. Specifically, a significant increase in D-D level is often regarded as a sensitive and early warning signal of thrombosis [10], while abnormal changes in FIB [11] and APPT [12] can indirectly reflect blood hypercoagulability. However, although these studies have revealed the potential association between coagulation factors and DVT, there are still insufficient studies on the correlation between serum coagulation factors and the risk of DVT in patients with pelvic tumors in the preoperative and postoperative periods, especially in the area of comprehensive analysis and systematic investigation by taking into account the clinical characteristics of the patients, including tumor stage, surgical approach, and postoperative recovery.

Therefore, this study aimed to investigate the correlation between serum coagulation factors and clinical characteristics in patients with pelvic tumors and to analyze the combined effects of these factors on the risk of DVT.

MATERIALS AND METHODS

Patients

Enrollment was granted to female patients diagnosed with pelvic tumors (ovarian, cervical, and endometrial cancers) who qualified for radical surgery, had not undergone any prior treatment, and were monitored for over three months after surgery, from March 2022 through December 2024. Individuals suffering from comorbid systemic tumors or blood-related conditions (e.g. leukemia, myelodysplastic syndromes), those on prolonged anticoagulant/antiplatelet medication (such as warfarin, aspirin), those with significant hepatic or renal deficiencies, preoperative pulmonary embolism, and those whose follow-up was unfeasible or whose data was not fully gathered were excluded.

A total of 161 patients were finally included, including 52 cases of ovarian cancer, 46 cases of cervical cancer, and 63 cases of endometrial cancer. The diagnosis of DVT was based on the Guidelines for the Diagnosis and Treatment of Deep Vein Thrombosis (3rd edition). Patients who were diagnosed with DVT preoperatively received subcutaneous injections of either 40 mg of heparin or enoxaparin daily, or 10 mg of oral anticoagulant rivaroxaban or warfarin. For DVT patients with significant risk to limb circulation who could not undergo anticoagulant treatment, a lower vena cava filter was placed as an interventional treatment. Patients continued anticoagulation therapy while awaiting surgery to prevent the thrombus from expanding further. For all patients, the decision on when to perform surgery was made by the attending physician or primary care team, taking into account clinical features, health status, coagulation, and the potential risks and benefits.

Data collection

General clinical characteristics of the patients were collected: age, weight, height, tumor type, International Federation of Gynecology and Obstetrics (FIGO) stage, and comorbidities. Laboratory data included thrombin time (TT), prothrombin time (PT), APTT, FIB, D-D, platelets (PLT), and plasminogen activator inhibitor-1 (PAI)-1. Body mass index (BMI) = weight (kg)/height^2 was calculated. Information about the patients' surgical procedures was collected: preoperative thrombolytic modalities (subcutaneous low molecular heparin, oral anticoagulants, and interventional modalities), intraoperative blood loss, postoperative bedtime, postoperative prophylactic thrombolytic therapy, and adjuvant treatments affecting anticoagulant function (e.g. chemotherapy, radiotherapy, and immunotherapy).

DVT assessment

Upon admission and three days post-surgery, all patients received color Doppler ultrasound examinations of their leg veins. Patients who reported the presence of clinical features associated with DVT, including sudden swelling and pain, depressed edema of the affected limb on palpation, increased soft tissue tone, and increased skin temperature, at follow-up within 3 months after surgery also underwent color Doppler ultrasound of the leg veins. The diagnosis of DVT was based on the Guidelines for the Diagnosis and Treatment of Deep Vein Thrombosis (3rd Edition), and ultrasonography was performed on patients with moderate (Wells score 1 and 2) and severe (Wells score ≥ 3) DVT. Possible DVT should be considered if ultrasonography detects blood flow signal defects, missing signals in the lumen center and periphery, and no blood flow upon squeezing the distal limb. Angiography was conducted to confirm the diagnosis if two ultrasound exams indicated DVT.

Statistics and analysis

Statistical analyses were performed using SPSS 22.0 software. To check the normality of the data, the Shapiro-Wilk test was employed. When the data were normally distributed, they were expressed as mean ± standard deviation, and comparisons between groups were made using Student's *t*-test. In cases of skewed distributions, continuous variable data were displayed as median (IQR), with the Mann-Whitney U-test used for comparing groups. Count data were expressed as frequencies (n) and ratios (%) and were tested using the chi-squared test. To screen risk factors for postoperative DVT, principal component analysis (PCA) was performed on continuous variables (age, PT, APTT, FIB, D-D, and PAI-1). With a p-value of less than 0.05 in Bartlett's test of sphericity, the data were found appropriate for PCA, and factors with higher PCA scores were considered in the binary logistic analysis. $p < 0.05$ in chi-squared test indicated that the model was valid. The predictive performance of the model was analyzed based on the AUC value of the ROC curve. Post hoc efficacy analyses were conducted using G*Power 3.1 software with a set effect size of 0.3 (medium effect), $\alpha = 0.05$, and a sample size of 161 cases, which showed a statistical power of 85%, indicating that the current sample size is sufficient to detect significant differences in the main variables.

RESULTS

Clinical characteristics and preoperative coagulation indices between patients with preoperative DVT and non-DVT

Table 1 illustrates clinical characteristics and preoperative coagulation indices in the preoperative DVT group (n = 22) and non-DVT group (n = 139). The mean age of patients in both groups was similar, 58 years (range 49 - 76 years) and 59 years (range 47 - 71 years), and the difference between the two groups was statistically non-significant ($p = 0.428$). BMI was also statistically non-significant ($p = 0.598$). In terms of tumor type and FIGO stage, the distribution of patients with ovarian, cervical, and endometrial cancers differed between the two groups. Specifically, there was a higher percentage of patients with ovarian cancer in the preoperative DVT group, while a lower percentage of cervical and endometrial cancers. It appeared that the proportion of patients with DVT was slightly higher in patients with advanced tumor stages (III and IV) than in early stages (I and II). The difference in the proportion of comorbidities, including diabetes mellitus, dyslipidemia, and hypertension, between the preoperative DVT and non-DVT groups was statistically non-significant. Regarding thrombolysis modalities, low molecular heparin and oral anticoagulants were mainly used in DVT patients. Regarding coagulation indices, TT values were not significantly different between the DVT and non-DVT groups ($p = 0.344$), whereas PT values were significantly higher in the preoperative DVT group than in the non-DVT group ($p < 0.001$). APTT values were lower in the preoperative DVT group than in the non-DVT group ($p = 0.002$). However, although FIB was slightly higher in the DVT group, there was no significant difference between the two groups ($p = 0.144$). Nevertheless, D-D values were significantly higher in the preoperative DVT group than in the non-DVT group ($p < 0.001$). PLT values were also not significantly different between the two groups ($p = 0.350$). Notably, PAI-1 values were significantly higher in the preoperative DVT group than in the non-DVT group ($p < 0.001$).

Clinical features, intraoperative data, and coagulation indices at 72 hours after surgery between patients with postoperative DVT and NDVT

After three months of postoperative follow-up, 35 patients continued to exhibit clinical signs of DVT, with 10 having been diagnosed with DVT preoperatively. One patient, diagnosed with DVT preoperatively, unfortunately suffered pulmonary embolism in the postoperative period and was therefore excluded from the follow-up study. Table 2 shows the characteristics of patients with postoperative DVT (n = 35) and NDVT (n = 125). The mean age of patients with DVT was higher than that of patients with NDVT ($p = 0.032$). BMI remained statistically insignificant between the two groups ($p = 0.629$).

The proportion of patients with ovarian and endometrial cancers was significantly higher in the DVT group than in the NDVT group ($p = 0.002$), whereas the proportion of patients with cervical cancer was similar in both groups ($p = 0.979$). Of interest, those with advanced FIGO were more likely to have DVT after surgery. The difference in the proportions of comorbidities between the two groups was statistically non-significant. The differences in minimally invasive surgery, bleeding greater than 1,000 mL, lymph node dissection, and positive surgical margins, were statistically non-significant

Table 1. Clinical characteristics and preoperative coagulation indices of patients with preoperative DVT and non-DVT.

Data	Pre-DVT (n = 22)	Pre-NDVT (n = 139)	p-value
Age (years)	58 (49, 76)	59 (47, 71)	0.428
BMI (kg/m²)	22.5 (17.5, 26.7)	23.2 (18.5, 27.4)	0.598
Tumor type and FIGO stage			
Ovarian cancer	14 (63.64)	38 (27.34)	0.001
I and II	3 (21.43, 3/14)	19 (50.00, 19/38)	0.064
III and IV	11 (78.57, 11/14)	19 (50.00, 19/38)	
Cervical cancer	5 (22.73)	41 (29.50)	0.514
I and II	1 (20.00, 1/5)	30 (73.17 30/41)	0.014
III and IV	4 (80.00, 4/5)	11 (26.83, 11/41)	
Endometrial cancer	3 (13.64)	60 (43.17)	0.008
I and II	1 (33.33, 1/3)	55 (91.67, 55/60)	0.03
III and IV	2 (66.67, 2/3)	5 (8.33, 5/60)	
Comorbidities			
Diabetes mellitus	4 (18.18)	15 (10.79)	0.318
Dyslipidemia	3 (13.64)	8 (5.76)	0.173
Hypertension	6 (27.27)	22 (15.83)	0.188
Thrombolysis modalities			
Low molecular heparin	9 (40.91)	0	
Oral anticoagulants	11 (50.00)	0	
VCF placement	2 (9.09)	0	
Coagulation indices			
TT (s)	13.81 ± 2.08	13.54 ± 1.01	0.344
PT (s)	13.64 ± 1.33	11.35 ± 1.00	< 0.001
APTT (s)	27.00 ± 4.59	27.75 ± 1.88	0.002
FIB (g/L)	2.85 ± 0.63	2.63 ± 0.64	0.144
D-D (μg/L)	178.02 ± 42.37	141.25 ± 28.36	< 0.001
PLT (× 10^9/L)	276.3 ± 61.21	265.30 ± 49.25	0.35
PAI-1 (ng/mL)	23.7 ± 4.2	18.71 ± 2.22	< 0.001

Pre-DVT preoperative deep vein thrombosis, NDVT non-deep vein thrombosis, FIGO International Federation of Gynecology and Obstetrics, IVCF inferior vena cava filter, TT thrombin time, PT prothrombin time, APTT activated partial thromboplastin time, FIB fibrinogen, D-D D-Dimer, PLT platelet, PAI-1 plasminogen activator inhibitor-1. p < 0.05 is statistically significant.

between the two groups. However, postoperative bedtime greater than 72 hours was significantly higher in the DVT group than in the NDVT group (p = 0.028). Regarding postoperative treatments, indicators of thrombolytic prophylaxis, adjuvant therapy, and immunotherapy differed between the two groups. Among them, the proportions of thrombolytic prophylaxis and adjuvant therapy were significantly higher in the DVT group than in the NDVT group (p = 0.016, p = 0.015).
The difference in TT between the two groups was statistically non-significant (p = 0.310). However, PT had significantly higher values in the DVT group than in the NDVT group (p < 0.001). APTT had a slightly lower mean value in the DVT group (p = 0.019), whereas FIB, D-D, and PAI-1 had significantly higher values than in the NDVT group (p < 0.001). The difference of PLT between the two groups was statistically non-significant.

Screening of factors for postoperative DVT

PCA was conducted for continuous variables such as age, PT, APTT, FIB, D-D, and PAI. A p-value of less than 0.001 from Bartlett's test of sphericity showed that principal component analysis could be carried out. Table 3 shows the extent to which each component contributes to the variance in the dataset. Six principal components collectively explained all the variance in the dataset. With a characteristic root of 1.72, the first principal component explained 28.674% of the variance. The

Table 2. Clinical characteristics, intraoperative data, and coagulation indices at 72 hours postoperatively in patients with postoperative DVT and NDVT.

Data	Post-DVT (n = 35)	Post-NDVT (n = 125)	p-value
Age (years)	66 (58, 76)	57 (44, 71)	0.032
BMI (kg/m²)	23.2 (18.7, 26.7)	23.1 (18.2, 27.4)	0.629
Tumor type and FIGO stage			
Ovarian cancer	19 (54.29)	33 (26.40)	0.002
I and II	3 (15.79, 3/19)	19 (57.58, 19/33)	0.003
III and IV	16 (84.21, 16/19)	14 (42.42, 14/33)	
Cervical cancer	10 (28.58)	36 (28.80)	0.979
I and II	3 (30.00, 3/10)	28 (77.78, 28/36)	0.004
III and IV	7 (70.00, 7/10)	8 (22.22, 8/36)	
Endometrial cancer	6 (17.14)	56 (44.80)	0.003
I and II	3 (50.00, 3/6)	52 (92.86, 52/56)	0.002
III and IV	3 (50.00, 3/6)	4 (7.14, 4/56)	
Comorbidities			
Diabetes mellitus	5 (14.29)	14 (11.20)	0.618
Dyslipidemia	3 (8.57)	7 (5.60)	0.457
Hypertension	8 (22.86)	20 (16.00)	0.345
Preoperative DVT	10 (28.57)	11 (8.80)	0.004
Surgical characteristics			
Minimally invasive surgery	5 (14.29)	20 (16.00)	0.805
Bleeding greater than 1,000 mL	2 (5.71)	5 (4.00)	0.648
Lymph node dissection	28 (80.00)	98 (80.33)	0.916
Positive surgical margins	11 (31.43)	34 (27.20)	0.623
Postoperative bedtime greater than 72 hours	9 (25.71)	13 (10.4)	0.028
Postoperative thrombolytic prophylaxis	18 (51.43)	37 (29.60)	0.016
Adjuvant therapy	29 (82.86)	76 (60.80)	0.015
Radiotherapy	10 (34.48, 10/29)	16 (24.24, 16/76)	0.426
Chemotherapy	18 (62.07, 18/29)	44 (70.97, 44/76)	
Immunotherapy	1 (3.45, 1/29)	6 (85.71, 6/76)	
Postoperative infection	2 (5.71)	5 (4.00)	0.648
Coagulation indicators			
TT (s)	13.80 ± 2.17	13.36 ± 2.01	0.31
PT (s)	14.34 ± 1.55	11.45 ± 2.17	< 0.001
APTT (s)	23.53 ± 3.88	26.74 (23.89, 30.11)	0.019
FIB (g/L)	3.15 ± 0.61	2.50 (2.15, 2.86)	< 0.001
D-D (μg/L)	184.89 ± 49.40	147.53 (116.70, 182.06)	< 0.001
PLT (× 10^9/L)	253.59 ± 52.46	250.85 (208.96, 290.23)	0.261
PAI-1 (ng/mL)	24.42 ± 5.08	21.84 (19.80, 23.79)	< 0.001

Categorical data are expressed as n (%), and continuous value are expressed as X ± S or M (IQR, quartiles).
Post-DVT postoperative deep vein thrombosis, NDVT non-deep vein thrombosis, FIGO International Federation of Gynecology and Obstetrics, IVCF inferior vena cava filter, TT thrombin time, PT prothrombin time, APTT activated partial thromboplastin time, FIB fibrinogen, D-D D-Dimer, PLT platelet, PAI-1 plasminogen activator inhibitor-1. $p < 0.05$ is statistically significant.

Table 3. Factor loading coefficients.

Variables	Factor loading coefficients			Common variance
	principal component 1	principal component 2	principal component 3	
Age	0.839	-0.36	0.005	0.833
PT	0.309	0.71	-0.226	0.651
APTT	-0.021	0.073	0.968	0.942
FIB	0.358	0.651	0.178	0.584
D-D	0.876	-0.229	0.033	0.822
PAI-1	0.155	0.335	-0.05	0.139

PT prothrombin time, APTT activated partial thromboplastin time, FIB fibrinogen, D-D D-Dimer, PLT platelet, PAI-1 plasminogen activator inhibitor-1.

Table 4. Weights of principal components.

Principal components	Variance (%)	Cumulative variance (%)	Weights (%)
PC1	0.287	28.674	43.322
PC2	0.205	49.132	30.909
PC3	0.171	66.188	25.769

PC1 principal component 1, PC2 principal component 2, PC3 principal component 3, PCA principal component analysis.

Table 5. Binary logic analysis.

Independent variable	Regression coefficient	Standard error	Z	p	OR	95% CI	
						upper limit	lower limit
Constants	-3.65	1.29	-2.83	0.005	0.03	0.00	0.33
Age	0.04	0.02	1.96	0.050	1.02	1.01	1.03
Preoperative DVT (yes)	1.26	0.68	1.87	0.062	3.53	0.94	13.25
D-D	0.02	0.01	3.37	0.001	1.02	1.01	1.03
Tumor type (vs. endometrial cancer)	-0.88	0.65	-1.35	0.178	0.42	0.12	1.49
Tumor type (vs. cervical cancer)	-1.26	0.70	-1.79	0.074	0.28	0.07	1.13
FIGO (vs. III and IV)	1.28	0.65	1.96	0.048	3.60	1.01	11.98
Prolonged bedtime (yes)	0.87	0.71	1.22	0.222	2.39	0.59	9.67
Thrombolytic prophylaxis (no)	1.05	0.53	1.97	0.049	2.85	1.01	8.09
Adjuvant therapy (yes)	1.33	0.64	2.08	0.038	1.02	1.01	1.03

OR odds ratio, CI confidence interval. $p < 0.05$ is statistically significant.

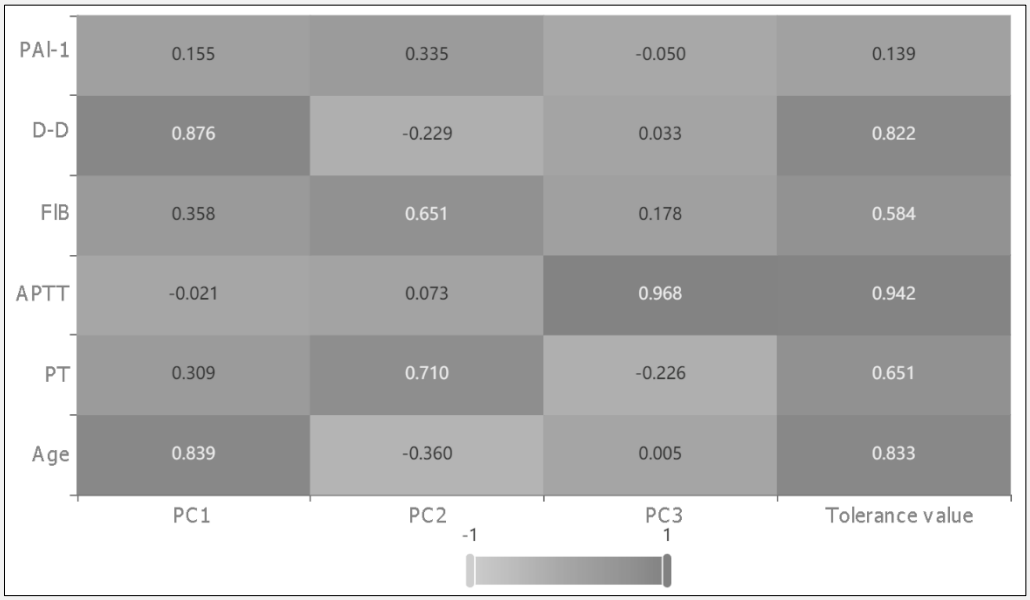

Figure 1. Heat map of factor loading matrix.

PC1 principal component 1, PC2 principal component 2, PC3 principal component 3, PCA principal component analysis.

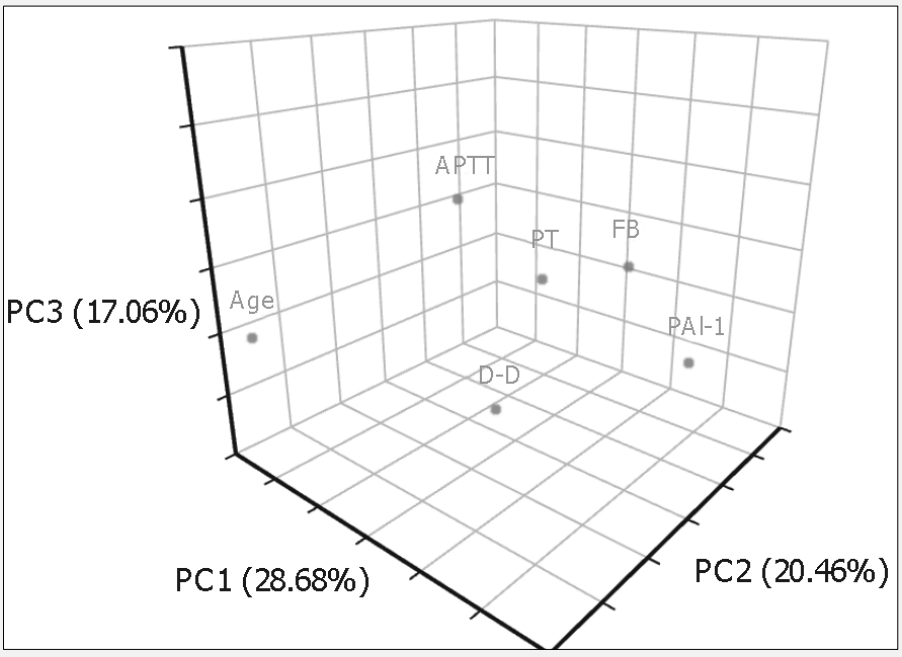

Figure 2. Three-dimensional analysis of factor loadings.

PC1 principal component 1, PC2 principal component 2, PC3 principal component 3, PCA principal component analysis.

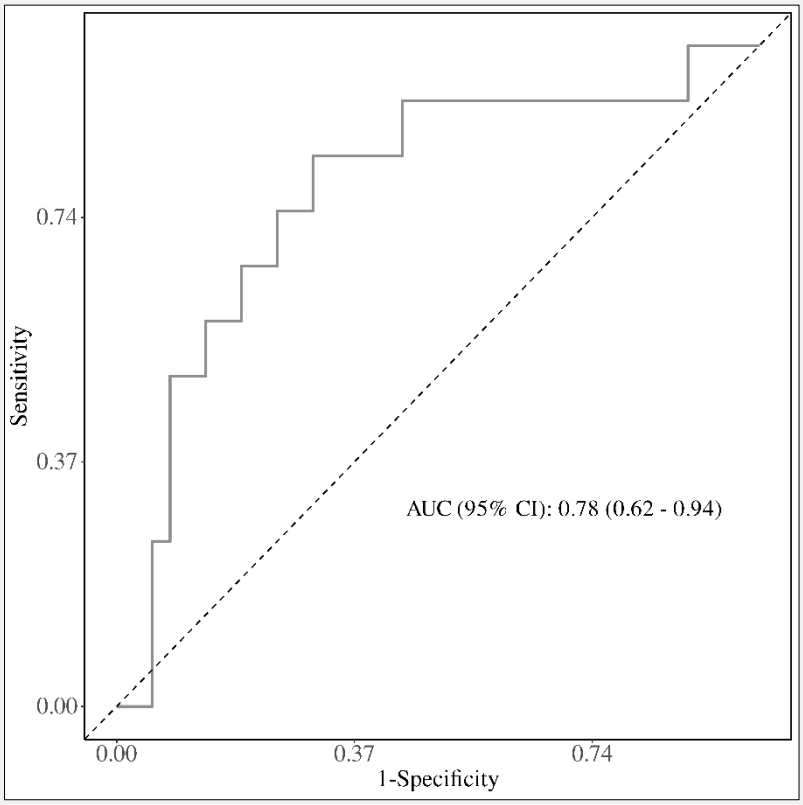

Figure 3. ROC curve of the model.

FPR false positive rate, TPR true positive rate.

second principal component, with a characteristic root of 1.227, accounted for 20.458% of the variance, and when combined with the first principal component, they explained a cumulative 49.132% of the variance. Further analysis showed that the third principal component had a characteristic root of 1.023 and explained 17.6% of the variance, raising the cumulative variance to 66.188%. The fourth principal component, with a characteristic root of 0.97, contributed 16.172% to the variance, bringing it to 82.36%. This indicates that the first four principal components together explain more than 82% of the variability in the dataset, which already summarizes the main features of the data well.

Figures 1 and 2 reveal the loading coefficients and common variance of each variable on different principal components and the factor loading analysis. Age had a higher loading on principal component 1 (0.839) and exhibited a greater common variance, indicating that principal component 1 better accounts for the variance in the age variable. Age had a loading of -0.36 on principal component 2, indicating a negative correlation with it, even though this correlation is weaker compared to principal component 1.

D-D had a higher loading (0.876) on principal component 1, as well as its common variance. On principal component 2, D-D had a loading of -0.229, showing some negative correlation with principal component 2. PT and FIB had similar loading distributions on principal component 1. However, the loading of APTT and PAI-1 was lower on all principal components.

Table 4 reveals weights of principal components. Principal component 1 explained 28.674% of the total variance and was the primary contribution whose weight was as high as 43.322%, which was covered most significantly in the component analysis. Principal component 2 subsequently accounted for 20.458% of the variance, bringing the cumulative total to 49.132%, and had a weight of 30.909%, highlighting its role in supplementing the data from principal component 1, albeit with a slightly lesser impact. Principal component 2 and principal component 3, although with diminishing weights, collectively enhanced the comprehensiveness of the

variance, especially in complex data structures where they reveal secondary and interaction effects.

Prediction model of DVT after pelvic tumor surgery

From the continuous factors listed earlier, D-D and age, which had significant contributions, were selected. The categorical variables (tumor type, FIGO stage, preoperative DVT, postoperative prolonged bedtime, postoperative thrombolytic prophylaxis, postoperative adjuvant therapy, D-D, and age) were included in the logistic analysis. Chi-squared test for the model showed a significance p-value of < 0.001, indicating that the model was valid. Table 5 shows age as one of the independent variables by logistic regression analysis with a coefficient of 0.04, indicating a positive correlation between age and the dependent variable ($p = 0.050$, OR = 1.02, 95% CI: 1.01 to 1.03). In addition, the table lists other independent variables that were significantly associated with postoperative DVT, such as elevated D-D, FIGO stage (III and IV), no postoperative prophylactic thrombolytic therapy, and postoperative adjuvant therapy. The AUC value for the model was 0.780 (95% confidence interval: 0.62 to 0.94, $p < 0.001$) (Figure 3).

DISCUSSION

This study centered on the risk factors for preoperative and postoperative DVT in patients with pelvic tumors, focusing on the associations of coagulation function indices, clinical characteristics, and surgery-related factors with DVT events. The results showed that postoperative DVT in patients with pelvic tumors was closely related to coagulation function abnormalities, tumor biological characteristics, and postoperative management strategies, and the key risk factors screened by PCA and logistic regression model had high predictive value for postoperative DVT.

The coagulation indices of patients in the preoperative DVT group were significantly prolonged in PT ($p < 0.001$), shortened in APTT ($p = 0.002$), and significantly elevated in D-D ($p < 0.001$) and PAI-1 ($p < 0.001$), indicating a critical role of the coagulation-fibrinolytic system imbalance in DVT. Prolongation of PT usually reflects activation of exogenous coagulation pathway, while shortening of APTT suggests activation of endogenous coagulation pathways, which may be related to procoagulant substances (e.g. tissue factors) in the tumor microenvironment [13,14]. In cancer patients, tissue factors are significant, acting as initiators of the external coagulation pathway and being closely related to cancer progression and metastasis [15]. Elevated D-D levels usually indicate persistent activation of the fibrinolytic system, which is particularly evident in patients with DVT, consistent with a tumor-associated hypercoagulable state [16]. In cancer patients, abnormal activation of the coagulation system not only increases the risk of thrombosis but may also promote tumor growth and metastasis [17]. Hypercoagulability in individuals with cancer is related to multiple factors, including the procoagulant traits of tumor cells, the inflammatory reactions of host cells, and the effects of treatments for cancer [18].

In the distribution of tumor types, the preoperative DVT group had a higher proportion of ovarian cancer and a lower proportion of cervical and endometrial cancers. This may relate to the biological behavior of ovarian cancer, which often advances until it is detected at a more advanced stage, typically with extensive peritoneal dissemination and a significant tumor load. In this situation, tumor cells release a variety of procoagulant substances, such as mucin protein and carcinoembryonic antigen, which activate the coagulation system and increase the risk of thrombosis [19]. Also, advanced ovarian cancer is combined with hemo-concentration caused by ascites [20], which may further increase the risk of DVT. In addition, the slightly higher proportion of DVT in patients with advanced FIGO (stages III and IV) suggests a potential association between tumor stage and thrombotic risk, which may be related to increased tumor aggressiveness, systemic inflammatory response, and exacerbation of vascular endothelial injury [21,22].

The mean age of patients was higher in the postoperative DVT group ($p = 0.032$), the proportion of ovarian and endometrial cancers was significantly higher than that of the NDVT group ($p = 0.002$), and patients with advanced stages of FIGO were more prone to postoperative DVT. Age has been reported to contribute to thrombosis in advanced-age patients with reduced vascular endothelial function, hemodynamic changes, and increased comorbidities [23]. The elevated risk of postoperative DVT in patients with advanced ovarian, cervical, and endometrial cancers may be associated with more complex and extensive surgery (e.g. lymph node dissection), prolonged postoperative recovery, and residual tumor-associated hypercoagulability. Notably, postoperative bedtime > 72 hours significantly increased the risk of DVT ($p = 0.028$). Prolonged PT, shortened APTT, and elevated FIB, D-D, and PAI-1 in the postoperative DVT group (all $p < 0.001$) suggested postoperative hypercoagulability (all $p < 0.001$). In addition, postoperative prophylactic anticoagulant therapy was applied in a higher proportion in the DVT group ($p = 0.016$), which may reflect the clinical identification and targeted intervention for high-risk patients. This was also suggested by a previous study [24]; however, the possibility of insufficient or resistant anticoagulation still needs to be guarded against.

PCA showed that age and D-D were the most significant factors explaining the variability of postoperative DVT (cumulative variance contribution of 49.132%). Age as a core variable in principal component 1 (loading 0.839) reflected its importance as a chronic risk factor, while the high loading of D-D in principal component 1 (0.876) indicated its sensitivity and specificity for acute thrombotic events. The logistic regression model further validated the independent predictive val-

ue of age, preoperative DVT, elevated D-D, and advanced FIGO (stages III and IV). For the risk of postoperative DVT in elderly patients with pelvic tumors, the researchers found that age was an independent risk factor for postoperative DVT. The incidence of DVT increases significantly with increasing age [25]. Elderly patients undergoing gynecologic oncology surgery face a greater risk of postoperative DVT. This risk may stem from their slower recovery and reduced mobility, which can result in poor blood circulation and subsequently elevate the risk [26]. Elevated D-D levels are strongly associated with postoperative DVT, especially in patients with advanced FIGO [27]. Dynamic monitoring of D-D levels can help clinicians to identify high-risk patients at an early stage and take appropriate preventive measures, such as anticoagulation therapy, to reduce the incidence of DVT. According to one study, receiving postoperative prophylactic anticoagulation significantly reduces the incidence of DVT [28]. It was observed that adjuvant chemotherapy (e.g. chemotherapy, radiotherapy, immunotherapy) after radical treatment increased the risk of DVT. The potential mechanisms involved are as follows: some drugs (e.g. cisplatin) damage the vascular endothelium and activate the coagulation system. Concomitant chemotherapy may trigger dehydration or the release of procoagulant substances from tumor cells, leading to viscous and hypercoagulable blood. Pelvic irradiation causes vascular inflammation and fibrosis, which can compress the veins or slow down the blood flow. Local inflammatory factors (e.g. IL-6) further activate the coagulation [29,30]. A DVT prediction model constructed based on multifactorial logistic regression (AUC = 0.780, 95% CI: 0.62 - 0.94) showed high risk stratification ability. The model integrated key variables such as tumor type, FIGO stage, adjuvant treatments, and postoperative management characteristics, which provided a quantitative basis for the clinical development of individualized anticoagulation strategies. For example, for high-risk patients it may be preferred to choose prophylactic anticoagulants combined with physical interventions, so as to optimize postoperative thrombosis prevention and control.

Limitations

This study has several limitations. First, the sample size was relatively small, particularly in the postoperative DVT group (n = 35). While PCA-based continuous variable reduction and post hoc power analysis indicated an 85% statistical power for the current sample size – sufficient to support conclusion reliability - the limited cohort may compromise external validity. Future studies should expand sample sizes to enhance generalizability. Second, although the study design incorporated chemotherapy/radiotherapy effects on coagulation, only composite adjuvant therapy (chemotherapy, radiotherapy, or immunotherapy) showed significant intergroup differences (DVT vs. non-DVT groups). The independent impacts of individual treatment modalities remain unresolved. Consequently, adjuvant therapy was modeled as a composite variable to control confounding, potentially obscuring modality-specific effects. Stratified analyses of therapeutic interventions warrant further investigation. Third, coagulation parameters were assessed only within 72 hours postoperatively, precluding dynamic monitoring and long-term follow-up. This temporal constraint limits insight into thrombotic risk evolution. Extending the observation window could elucidate temporal trends in coagulation profiles. To address these limitations, we propose the following: multi-center collaboration to enlarge sample sizes and extend follow-up durations (≥ 6 months recommended); granular documentation and independent effect analysis of therapeutic regimens. Clinical recommendations are as follows: enhanced monitoring and personalized interventions are advised for high-risk cohorts: advanced ovarian cancer patients (FIGO stages III and IV); preoperative D-D or PAI-1 levels > 1.5 × upper limit of normal; patients requiring > 72 hours postoperative bedrest or undergoing extensive/complex surgeries. For these populations, we advocate the following: combined prophylaxis: mechanical measures (e.g. intermittent pneumatic compression) with pharmacologic anticoagulation (e.g. low-molecular-weight heparin); dynamic risk management: serial monitoring of D-D/PAI-1 levels to guide real-time adjustment of thromboprophylaxis strategies.

CONCLUSION

In patients with pelvic tumors, postoperative DVT arises from a multifaceted pathological process involving coagulation system abnormalities, tumor biology, and perioperative management strategies. Multivariate analysis confirmed that patient age, plasma D-D level, FIGO stage, duration of postoperative bed rest, and adjuvant therapeutic regimen were all independent predictors of postoperative DVT development. The clinical value of the risk assessment model constructed in this study is mainly reflected in two aspects: 1) it realizes the precise identification of high-risk groups and provides a quantitative basis for the development of individualized thrombosis prevention strategies; 2) through dynamic risk assessment, it refines anticoagulation therapy decisions, leading to improved clinical outcomes by balancing thrombosis prevention with bleeding risk. This model offers a scientific decision-making aid for developing a system that prevents and controls thrombosis during the perioperative period for pelvic tumors, and it could be translated into clinical practice.

Availability of Data and Materials:

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Ethics Approval Statement:
The present study was approved by the Ethics Committee of Shanxi Bethune Hospital (no. 2021BQE1011), and written informed consent was provided by all patients prior to the study start. All procedures were performed in accordance with the ethical standards of the Institutional Review Board and the Declaration of Helsinki, and its later amendments or comparable ethical standards.

Consent to Participate:
Written informed consent was obtained from each subject.

Consent for Publication:
Written informed consent for publication was obtained from all participants.

Declaration of Interest:
The authors have no conflicts of interest to declare.

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