Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Development and Internal Validation of a Nomogram for Early Postoperative Risk Stratification of Lower Extremity Deep Vein Thrombosis After Resection of Gastric and Colorectal Cancer in Patients Receiving Pharmacologic Thromboprophylaxis

yuanyuan ma
Department of Laboratory Medicine,Shaoxing People's Hospital
Xiong Sun
Department of Gastrointestinal Surgery, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology
qing wang
nancy20231230163.com
Department of Laboratory Medicine,Shaoxing People's Hospital

Research Article

Keywords: gastric or colorectal cancers, deep vein thrombosis, nomogram, risk stratification, prophylactic anticoagulation

Posted Date: May 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9386392/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Objective

To identify independent perioperative predictors of early postoperative lower extremity deep vein thrombosis (DVT) in patients undergoing surgery for gastric or colorectal cancer despite routine pharmacologic thromboprophylaxis, and to develop and internally validate a nomogram for early postoperative risk stratification.

Methods

This retrospective study included adult patients with pathologically confirmed gastric or colorectal cancer who underwent surgical resection at Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, between December 2020 and October 2023. All included patients received routine postoperative low-molecular-weight heparin prophylaxis initiated 12 h after surgery according to institutional practice. The primary outcome was newly detected lower extremity DVT, including both distal and proximal events, identified by routine compression ultrasonography with color Doppler performed on postoperative day 3 regardless of symptoms. Eligible patients were randomly assigned to a training cohort and a validation cohort at a ratio of 7:3. Univariate analysis and multivariable logistic regression were used to identify independent predictors, which were then incorporated into a nomogram. Model performance was assessed by discrimination, calibration, and decision curve analysis.

Results

A total of 388 eligible patients were included, among whom 124 (32.0%) had postoperative lower extremity DVT detected on routine ultrasonographic screening. Multivariable logistic regression identified age, activated partial thromboplastin time (APTT), prothrombin time (PT), and postoperative day 1 D-dimer as independent predictors of postoperative DVT. The nomogram showed acceptable discrimination, with an area under the ROC curve of 0.787 (95% CI, 0.731–0.844) in the training cohort and 0.854 (95% CI, 0.774–0.934) in the validation cohort. Calibration curves demonstrated good agreement between predicted and observed probabilities, and decision curve analysis suggested potential clinical utility within a range of threshold probabilities.

Conclusion

Age, APTT, PT, and postoperative day 1 D-dimer were independently associated with early postoperative lower extremity DVT in this cohort. The resulting nomogram may assist early postoperative risk stratification and support closer surveillance of patients at increased risk; however, external validation is required before broader clinical application.

Introduction

Venous thromboembolism (VTE), including deep vein thrombosis (DVT) and pulmonary embolism (PE), is a common and potentially life-threatening complication in surgical patients[1, 2]. Patients with malignancies are particularly susceptible to VTE because of cancer-associated hypercoagulability, treatment-related vascular injury, perioperative immobilization, and systemic inflammatory responses[3, 4]. Previous studies have shown that the risk of VTE in patients with cancer is substantially higher than that in the general population, and PE remains an important cause of death independent of cancer progression itself [3, 4]. Therefore, timely identification of patients at high risk of postoperative thrombosis is essential for optimizing perioperative management and improving clinical outcomes[2, 5].

Patients with gastric or colorectal cancers represent a particularly high-risk population for postoperative thrombotic events[4, 6–10]. In addition to tumor-related hypercoagulability, gastrointestinal cancer surgery is often associated with extensive tissue trauma, prolonged operative duration, delayed ambulation, and complex perioperative management, all of which may further increase the risk of lower extremity DVT[4, 6, 7]. Once DVT occurs, it may prolong hospitalization, increase healthcare burden, and predispose patients to PE and other adverse outcomes[7, 8]. Therefore, early risk stratification for postoperative lower extremity DVT in patients with gastric or colorectal cancers is of considerable clinical importance[6, 8, 11].

The Caprini risk assessment model is widely used for VTE risk stratification in surgical patients and has been recommended by several clinical guidelines[2, 12–16]. However, in patients undergoing surgery for gastrointestinal malignancies, Caprini scores are often concentrated in the high-risk range, thereby limiting the model's discriminatory ability for more refined postoperative DVT stratification[11, 18–20]. Therefore, complementary approaches based on objective perioperative variables may be helpful for more individualized early postoperative risk assessment.

An early postoperative risk stratification tool based on objective perioperative variables may complement conventional risk assessment in this setting. In particular, among patients undergoing surgery for gastric or colorectal cancer despite routine pharmacologic thromboprophylaxis, identifying those at persistently increased risk of postoperative DVT may help optimize early postoperative surveillance. Accordingly, the present study aimed to identify independent perioperative predictors of postoperative lower extremity DVT and to develop and internally validate a nomogram for early postoperative risk stratification in this population.

Materials and Methods

Study design and patients

This retrospective study included patients with pathologically confirmed gastric or colorectal cancers who were hospitalized at Union Hospital, Tongji Medical College, Huazhong University of Science and

Technology, between December 2020 and October 2023. This study was approved by the Ethics Committee of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology (Approval No. [2022] 0594). The requirement for informed consent was waived owing to the retrospective design of the study.

The inclusion criteria were as follows: (1) patients with pathologically confirmed gastric cancer or colorectal cancer who underwent surgical resection; (2) age ≥ 18 years; (3) no history of other malignancies; (4) no history of VTE; (5) availability of both preoperative and postoperative lower extremity venous ultrasonography; and (6) no acute infection. The exclusion criteria were as follows: (1) incomplete clinical data; (2) preoperative lower extremity DVT detected on venous ultrasonography; and (3) absence of routine postoperative prophylactic anticoagulation with low-molecular-weight heparin (LMWH).

Data collection

Clinical data were retrieved from the electronic medical records, including demographic characteristics, comorbidities, perioperative variables, and laboratory parameters. Demographic and clinical variables included age, sex, body mass index (BMI), hypertension, diabetes mellitus, coronary heart disease, pulmonary ventilation dysfunction, and postoperative Caprini score. Perioperative variables included operative time and surgical approach.

Preoperative laboratory parameters were defined as the most recent values obtained before surgery, and postoperative day 1 D-dimer referred to the first D-dimer measurement obtained on the first postoperative day according to routine institutional testing. The postoperative Caprini score was assessed during the early postoperative period using routinely documented clinical information. Laboratory variables included preoperative white blood cell count (WBC), red blood cell count (RBC), hemoglobin (HGB), platelet count (PLT), neutrophil count (NEUT), lymphocyte count (LY), monocyte count (MONO), albumin (ALB), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL), D-dimer, prothrombin time (PT), activated partial thromboplastin time (APTT), thrombin time (TT), fibrinogen (FIB), fibrinogen degradation products (FDP), and antithrombin III (AT-III), as well as postoperative day 1 D-dimer. All data were independently extracted and cross-checked by two surgeons.

Outcome definition and perioperative thromboprophylaxis

The primary outcome was postoperative lower extremity DVT, defined as newly detected thrombosis on routine postoperative lower extremity venous ultrasonography. All eligible patients underwent routine compression ultrasonography with color Doppler on postoperative day 3, regardless of symptoms, and all examinations were independently performed by two experienced sonographers. DVT was diagnosed when heterogeneous echogenic intraluminal material was identified within the venous lumen,

accompanied by absent or reduced color Doppler flow signals and incomplete venous compressibility. Thrombotic events involving the peroneal, posterior tibial, popliteal, femoral, or iliac veins were considered outcome events. Accordingly, both distal and proximal lower extremity DVT were included in the primary outcome. If patients developed symptoms suggestive of pulmonary embolism, computed tomography pulmonary angiography was performed for further evaluation. Because routine postoperative ultrasonographic screening was performed in all eligible patients, including asymptomatic individuals, the observed incidence of DVT in this cohort may have been higher than that reported in studies restricted to symptomatic events. Because routine postoperative ultrasonographic screening was performed in all eligible patients, including asymptomatic individuals, the primary outcome represented screening-detected postoperative DVT rather than symptomatic events alone. Distal and proximal DVT were both included in the primary analysis, and their anatomical distribution was additionally summarized descriptively.

All included patients received routine postoperative pharmacological thromboprophylaxis with LMWH (nadroparin calcium) according to institutional practice and the manufacturer's instructions. Prophylactic anticoagulation was initiated 12 h after surgery, with dose adjustment based on body weight. No routine mechanical thromboprophylaxis was applied. During the early postoperative period, patients were encouraged to perform active in-bed mobilization as tolerated. After postoperative DVT was confirmed, anticoagulation was escalated to a therapeutic regimen in accordance with institutional management protocols.

Model development and internal validation

Eligible patients were randomly assigned to a training cohort and a validation cohort at a ratio of 7:3. The training cohort was used for model development, and the validation cohort was used for split-sample internal validation. Candidate predictors were selected from clinically relevant perioperative variables routinely available in practice. Univariate analyses were used as an initial screening step, and variables showing potential associations ($P < 0.10$) together with variables considered clinically important were entered into the multivariable logistic regression model. Potential collinearity among coagulation-related variables was assessed before final model specification. A nomogram was then constructed based on the final multivariable model.

Statistical analysis

All statistical analyses were conducted using SPSS version 26.0 and R version 4.0.2. Continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range, IQR), as appropriate, and categorical variables were expressed as frequencies and percentages. Between-group comparisons were performed using the independent-samples t test or Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Model performance was evaluated in both the training and validation cohorts. Discrimination was assessed using the area under the receiver operating characteristic curve (AUC) and

the concordance index (C-index), calibration was evaluated using calibration curves, and clinical utility was assessed using decision curve analysis (DCA). Cases with incomplete key data were excluded from the final analysis, and no imputation was performed. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Patient enrollment and baseline characteristics

A total of 388 patients with gastric or colorectal cancers who met the inclusion and exclusion criteria were included in the present study. Among them, 124 developed postoperative lower extremity DVT, yielding an overall incidence of 32.0% (124/388). Eligible patients were randomly assigned to a training cohort (n = 272) and a validation cohort (n = 116) at a ratio of 7:3. The incidence of postoperative lower extremity DVT was 32.0% (87/272) in the training cohort and 31.9% (37/116) in the validation cohort, indicating a comparable distribution of outcome events between the two cohorts.

Baseline demographic, clinical, surgical, and laboratory characteristics of the two cohorts are summarized in Table 1. No statistically significant differences were observed between the training and validation cohorts with respect to age, sex, central venous catheterization, neoadjuvant therapy, smoking history, drinking history, pulmonary ventilation dysfunction, body mass index, operative time, surgical approach, or postoperative Caprini score (all $P > 0.05$). Likewise, no significant intergroup differences were identified in preoperative hematologic, biochemical, or coagulation-related variables, including white blood cell count, red blood cell count, hemoglobin, platelet count, neutrophil count, lymphocyte count, monocyte count, albumin, lipid profiles, D-dimer, fibrinogen degradation products, antithrombin III, prothrombin time, international normalized ratio, activated partial thromboplastin time, fibrinogen, thrombin time, or postoperative day 1 D-dimer (all $P > 0.05$). These findings indicate that the two cohorts were generally well balanced.

Table 1
Characteristics of patients in the training and validation cohorts

Variable	Training cohort(n = 272)	Validation cohort(n = 116)	P value
Age	59.68 ± 10.93	58.49 ± 11.38	0.370
Sex	184(67.6%)	83 (71.6%)	0.521
Central venous catheterization	6 (2.2%)	3 (2.6%)	1.000
Neoadjuvant therapy	45 (16.5%)	18 (15.5%)	0.919
History of hypertension	85 (31.2%)	33 (28.4%)	0.668
History of diabetes mellitus	26 (9.6%)	12 (10.3%)	0.958
History of coronary heart disease	19 (7%)	12 (10.3%)	0.361
History of smoking	55 (20.2%)	22 (19%)	0.884
History of alcohol use	40 (14.7%)	18 (15.5%)	0.960
Pulmonary ventilation dysfunction	104 (38.2%)	49 (42.2%)	0.531
BMI (kg/m²)	23.24 ± 3.37	23.09 ± 3.07	0.677
Laparoscopic surgery	270 (99.3%)	114 (98.3%)	0.586
Operative time (min)	269.87 ± 78.42	263.22 ± 80.86	0.454
Caprini score	9.83 ± 1.42	9.89 ± 1.48	0.503
WBC (G/L)	5.29 ± 1.99	5.31 ± 1.69	0.595
RBC (T/L)	4.00 ± 0.56	3.96 ± 0.68	0.295
HGB (g/L)	118.14 ± 22.76	115.27 ± 24.3	0.197
PLT (G/L)	223.17 ± 87.05	232.05 ± 90.31	0.247
NEUT (G/L)	3.13 ± 1.74	3.15 ± 1.25	0.345
LY (G/L)	1.54 ± 0.51	1.51 ± 0.58	0.327
MONO (G/L)	0.43 ± 0.17	0.42 ± 0.15	0.657
ALB (g/L)	38.83 ± 4.14	38.68 ± 4.44	0.750
TC (mmol/L)	4.19 ± 0.91	4.22 ± 0.81	0.732
TG (mmol/L)	1.30 ± 0.85	1.28 ± 0.83	0.893
HDL (mmol/L)	1.13 ± 0.32	1.17 ± 0.37	0.354
LDL (mmol/L)	2.56 ± 0.78	2.54 ± 0.64	0.701

Variable	Training cohort(n = 272)	Validation cohort(n = 116)	P value
D-dimer (mg/L)	0.50 ± 0.47	0.73 ± 1.55	0.226
FDP (μg/mL)	3.00 ± 1.49	3.35 ± 3.68	0.933
AT-III (%)	92.70 ± 11.79	93.07 ± 11.14	0.768
PT (s)	13.41 ± 2.51	13.22 ± 0.71	0.650
INR	1.02 ± 0.07	1.04 ± 0.29	0.597
APTT (s)	37.30 ± 3.95	37.30 ± 3.58	0.803
FIB (g/L)	3.28 ± 0.85	3.25 ± 0.78	0.938
TT (s)	18.51 ± 12.35	17.61 ± 1.82	0.571
postoperative day 1 D-dimer (mg/L)	2.89 ± 2.80	2.74 ± 2.65	0.802

Univariate analysis of factors associated with postoperative lower extremity DVT

To identify candidate predictors of postoperative lower extremity DVT, univariate analyses were first performed in the training cohort. As shown in Table 2, pulmonary ventilation dysfunction (P = 0.001), age (P < 0.001), postoperative Caprini score (P < 0.001), preoperative albumin (P = 0.001), antithrombin III (P = 0.009), prothrombin time (PT; P = 0.004), international normalized ratio (INR; P = 0.005), preoperative D-dimer (P < 0.001), and postoperative day 1 D-dimer (P < 0.001) were significantly associated with postoperative DVT. Activated partial thromboplastin time (APTT; P = 0.075) and fibrinogen degradation products (FDP; P = 0.086) showed borderline associations.

Table 2
Univariate and multivariable analyses of factors associated with postoperative lower extremity DVT in the training cohort

Variable	DVT group (n = 87)	Non-DVT group (n = 185)	P value	Adjusted OR	95% CI	P value
Sex	56(64.3%)	128(69.2%)	0.428			
Central venous catheterization	3(3.4%)	3(1.6%)	0.388			
Neoadjuvant therapy	15(17.2%)	30(16.2%)	0.832			
History of hypertension	29(33.3%)	56(30.3%)	0.611			
History of diabetes mellitus	8(9.2%)	18(15.1%)	0.889			
History of coronary heart disease	9(10.3%)	10(5.4%)	0.136			
History of smoking	18(20.7%)	37(20.0%)	0.895			
History of alcohol use	13(14.9%)	27(14.6%)	0.940			
Pulmonary ventilation dysfunction	46(52.9%)	58(31.4%)	0.001			
Age	64.00(57.00,69.00)	57.00 (49.50,64.00)	< 0.001	1.062	1.031–1.094	< 0.001
BMI (kg/m²)	23.41(20.76,25.61)	22.91(20.57,25.94)	0.661			
Laparoscopic surgery	86(98.9%)	184(99.5%)	0.538			
Operative time (min)	268.71 ± 78.72	272.32 ± 78.15	0.724			
Caprini score	10.32 ± 1.34	9.59 ± 1.40	< 0.001			
WBC (G/L)	5.36 ± 2.19	5.12 ± 1.47	0.350			
RBC (T/L)	4.03 ± 0.54	3.92 ± 0.59	0.124			
HGB (g/L)	119.61 ± 22.11	115.02 ± 23.88	0.124			
PLT (G/L)	220.21 ± 89.85	229.45 ± 80.91	0.415			

Variable	DVT group (n = 87)	Non-DVT group (n = 185)	P value	Adjusted OR	95% CI	P value
Neut (G/L)	3.17 ± 1.94	3.05 ± 1.19	0.596			
LY (G/L)	1.57 ± 0.54	1.47 ± 0.44	0.115			
MONO (G/L)	0.43 ± 0.15	0.42 ± 0.18	0.660			
ALB (g/L)	37.58 ± 4.66	39.41 ± 3.73	0.001			
TC (mmol/L)	4.22 ± 0.91	4.12 ± 0.89	0.408			
TG (mmol/L)	1.33 ± 0.77	1.23 ± 0.98	0.382			
HDL (mmol/L)	1.12 ± 0.30	1.15 ± 0.35	0.432			
LDL (mmol/L)	2.57 ± 0.79	2.51 ± 0.74	0.564			
D-dimer (mg/L)	0.44(0.29,0.76)	0.30(0.23,0.44)	< 0.001			
FDP (μg/mL)	2.88 ± 1.47	3.22 ± 1.49	0.086			
AT-III (%)	93.96 ± 11.99	89.99 ± 10.91	0.009			
PT (s)	13.40 ± 0.70	13.13 ± 0.76	0.004	1.831	1.183–2.835	0.007
INR	1.01 ± 0.07	1.03 ± 0.06	0.005			
APTT (s)	36.73 ± 3.65	37.56 ± 3.52	0.075	0.880	0.804–0.964	0.006
FIB (g/L)	3.27 ± 0.88	3.27 ± 0.78	0.960			
TT (s)	17.60(16.85,18.60)	17.80(17.00,18.62)	0.288			
postoperative day 1 D-dimer (mg/L)	3.93 ± 3.37	2.18 ± 2.01	< 0.001	1.310	1.114–1.540	0.001

No significant associations were observed for sex, central venous catheterization, neoadjuvant therapy, hypertension, diabetes mellitus, coronary heart disease, smoking history, drinking history, BMI, laparoscopic surgery, operative time, white blood cell count, red blood cell count, hemoglobin, platelet count, neutrophil count, lymphocyte count, monocyte count, total cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, fibrinogen, or thrombin time (all $P > 0.05$). These findings suggest that only a limited subset of perioperative variables showed potential discriminatory value for postoperative DVT risk in this cohort.

Among the categorical variables, pulmonary ventilation dysfunction was more frequent in patients who developed postoperative DVT than in those who did not (52.9% vs. 31.4%, $P = 0.001$). This variable was therefore included in the subsequent multivariable analysis.

Multivariable logistic regression analysis

Variables identified in the univariate analysis were entered into a multivariable logistic regression model to identify independent predictors of postoperative lower extremity DVT. The final multivariable model demonstrated that age, APTT, PT, and postoperative day 1 D-dimer were independently associated with postoperative DVT in patients with gastric or colorectal cancers. Specifically, age was positively associated with postoperative DVT risk (OR = 1.062, P < 0.001, 95% CI: 1.031–1.094). PT was also independently associated with an increased risk (OR = 1.831, P = 0.007, 95% CI: 1.183–2.835), and postoperative day 1 D-dimer remained a significant positive predictor (OR = 1.310, P = 0.001, 95% CI: 1.114–1.540). In contrast, APTT was inversely associated with postoperative DVT risk (OR = 0.880, P = 0.006, 95% CI: 0.804–0.964).

Although pulmonary ventilation dysfunction, postoperative Caprini score, preoperative albumin, antithrombin III, INR, and preoperative D-dimer were associated with postoperative DVT in the univariate analysis, these variables were not retained in the final multivariable model. This finding suggests that these variables were not retained after multivariable adjustment or may have overlapped with more directly relevant coagulation-related indicators. Overall, the final model retained four clinically accessible variables for subsequent nomogram construction.

Construction of the nomogram

Based on the final multivariable logistic regression model, a nomogram was constructed incorporating the four independent predictors identified above, namely age, APTT, PT, and postoperative day 1 D-dimer (Fig. 1). In the nomogram, each predictor was assigned a point value according to its relative contribution to the model. The total score was obtained by summing the points for all included predictors, and the corresponding level of early postoperative DVT risk could then be estimated from the total score. Higher total scores indicated a greater risk of postoperative DVT.

Because all variables included in the nomogram are routinely available in perioperative clinical practice, the model may have potential utility for early postoperative risk stratification and for identifying patients who may require closer postoperative surveillance. In particular, the inclusion of coagulation-related variables and postoperative day 1 D-dimer suggests that the model reflects not only patient-related characteristics but also early postoperative physiological changes relevant to thrombosis formation.

Discriminatory performance of the nomogram

The discriminatory performance of the nomogram was evaluated using ROC curve analysis. In the training cohort, the AUC was 0.787 (95% CI: 0.731–0.844), indicating good discrimination. In the validation cohort, the AUC was 0.854 (95% CI: 0.774–0.934), further supporting the favorable performance of the model in the internal validation cohort. These results suggest that the nomogram was able to distinguish patients with postoperative lower extremity DVT from those without DVT with acceptable to good accuracy (Fig. 2).

The C-index was 0.787 in the training cohort and 0.854 in the validation cohort, consistent with the AUC findings and further supporting the satisfactory discriminative performance of the model. The slightly higher AUC and C-index in the validation cohort may reflect sampling variation, but overall the model showed acceptable performance in split-sample internal validation, although the higher AUC in the validation cohort may reflect sampling variation.

Calibration performance of the nomogram

Calibration curves were generated to assess the agreement between predicted and observed probabilities of postoperative lower extremity DVT. In both the training and validation cohorts, the calibration curves demonstrated good consistency between predicted and actual outcomes (Fig. 3), indicating acceptable calibration of the nomogram.

Taken together, these findings indicate that the nomogram based on age, APTT, PT, and postoperative day 1 D-dimer showed favorable model performance for postoperative lower extremity DVT in patients with gastric or colorectal cancers.

Clinical utility of the nomogram

Decision curve analysis showed a higher net benefit for the nomogram than the treat-all and treat-none strategies across a range of threshold probabilities, suggesting potential utility for guiding closer postoperative surveillance rather than directly determining treatment escalation (Fig. 4).

Discussion

In this retrospective single-center study, we developed a nomogram for early postoperative risk stratification of lower extremity DVT in patients undergoing surgery for gastric or colorectal cancer despite routine LMWH prophylaxis. The model incorporated four routinely available variables—age, PT, APTT, and postoperative day 1 D-dimer—and showed acceptable discrimination and calibration in split-sample internal validation. These findings suggest that objective perioperative variables may help identify patients who warrant closer early postoperative surveillance.

Age was identified as an independent predictor of postoperative lower extremity DVT in our study, which is consistent with previous epidemiological evidence showing that the incidence of VTE increases markedly with advancing age[24–26]. Several mechanisms may explain this association. Older individuals are more likely to exhibit age-related alterations in coagulation and fibrinolytic balance, reduced venous return due to impaired muscle pump function, endothelial dysfunction, and decreased venous valve competence, all of which may contribute to thrombogenesis[25–27]. In the setting of gastric or colorectal cancers, these age-related changes may be further amplified by tumor-associated hypercoagulability, perioperative tissue injury, and postoperative immobilization. Therefore, advanced age may be an important consideration in postoperative risk assessment and thromboprophylaxis[24–27].

Coagulation-related parameters also played an important role in the present model. PT and APTT are widely used laboratory indicators reflecting the extrinsic and intrinsic coagulation pathways, respectively, whereas D-dimer is a marker of fibrin turnover and ongoing thrombus formation[28–30]. In the multivariable analysis, PT and postoperative day 1 D-dimer were positively associated with postoperative lower extremity DVT, whereas APTT showed an inverse association. These findings suggest that perioperative coagulation activation may be closely related to early postoperative thrombosis in patients with gastric or colorectal cancers. The inverse association between APTT and postoperative DVT risk should be interpreted cautiously, as perioperative coagulation parameters may be influenced by multiple clinical factors and perioperative interventions. In particular, postoperative day 1 D-dimer may provide additional information beyond baseline clinical features by reflecting early postoperative prothrombotic changes[30]. Because these variables are routinely measured in clinical practice, they may be useful for bedside risk stratification.

The Caprini score is one of the most widely used tools for VTE risk assessment in surgical patients and has been incorporated into several clinical guidelines[2, 14–16]. However, its utility may be limited in patients with abdominal malignancies, in whom a large proportion of patients are already classified as high risk[11, 18–20]. In our cohort, postoperative Caprini scores were generally high, whereas only a subset of patients developed postoperative lower extremity DVT. This finding suggests that although the Caprini model remains useful for identifying patients who warrant thromboprophylaxis, its ability to further discriminate risk within a uniformly high-risk gastrointestinal cancer population may be limited. By contrast, the nomogram developed in the present study integrates several objective perioperative variables and may provide more individualized risk estimation in this setting.

Another notable finding of this study is that the proposed nomogram showed satisfactory model performance in both the training and internal validation cohorts. The AUC was 0.787 in the training cohort and 0.854 in the validation cohort, and the corresponding C-index values were identical to the AUC values. In addition, the calibration curves demonstrated good agreement between predicted and observed probabilities of postoperative lower extremity DVT. In addition, decision curve analysis suggested that the nomogram may provide favorable net clinical benefit within a practical range of threshold probabilities, supporting its potential utility in early postoperative surveillance. Taken together, these results suggest that the model has acceptable performance for early postoperative risk stratification of lower extremity DVT. Because the included predictors are simple and routinely available, the nomogram may be useful for identifying patients who warrant closer early postoperative surveillance. However, whether its use can improve clinical outcomes or guide individualized thromboprophylactic strategies requires further prospective investigation and external validation.

Several limitations should be acknowledged. First, this was a retrospective single-center study and is therefore subject to selection bias and residual confounding. Second, internal validation was performed using random split-sample validation rather than external validation or bootstrap-based optimism correction, and the model therefore requires further confirmation in independent cohorts. Third, predictor selection partly relied on univariate screening, which may limit model stability. Fourth, the primary

outcome included both distal and proximal DVT detected through routine postoperative ultrasonographic screening, including asymptomatic events, which may have increased the observed event rate and may limit direct comparison with studies focusing on symptomatic or clinically overt VTE. Finally, some clinically relevant perioperative variables were not available in the retrospective dataset.

Conclusion

In this cohort of patients undergoing surgery for gastric or colorectal cancer despite routine pharmacologic thromboprophylaxis, age, PT, APTT, and postoperative day 1 D-dimer were independently associated with early postoperative lower extremity DVT. A nomogram incorporating these variables showed acceptable performance for early postoperative risk stratification and may support closer postoperative surveillance. External validation is necessary before routine clinical implementation.

Declarations

Ethics approval and consent to participate

The requirement for informed consent was waived owing to the retrospective nature of the study. This study was approved by the institutional review board of Union Hospital Tongji Medical College, Huazhong University of Science and Technology(approval no. [2022] 0594).

Consent for publication

No applicable.

Competing interests

The authors declare no competing interests

Funding

None.

Author Contribution

Yuanyuan Ma: Investigation, Data curation, Resources, Writing original draft. Xiong Sun: Data curation; Resources; Methodology. Qing Wang: Conceptualization, Supervision, Validation.

Data availability

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

References

1. Björklund J, Rautiola J, Zelic R, et al. Risk of Venous Thromboembolic Events After Surgery for Cancer. JAMA Netw Open Feb. 2024;7(2):e2354352.
2. Anderson DR, Morgano GP, Bennett C, et al. American Society of Hematology 2019 guidelines for management of venous thromboembolism: prevention of venous thromboembolism in surgical hospitalized patients. Blood Adv Dec. 2019;3(23):3898–944.
3. Khorana AA. Venous thromboembolism and prognosis in cancer. Thromb Res Jun. 2010;125(6):490–3.
4. Donnellan E, Khorana AA. Cancer and Venous Thromboembolic Disease: A Review. Oncologist Feb. 2017;22(2):199–207.
5. Farge D, Frere C, Connors JM, et al. 2022 international clinical practice guidelines for the treatment and prophylaxis of venous thromboembolism in patients with cancer, including patients with COVID-19. Lancet Oncol Jul. 2022;23(7):e334–47.
6. Thereaux J, Badic B, Fuchs B, et al. From early risk to 1-year mortality: a comprehensive assessment of postoperative venous thromboembolism in upper gastrointestinal cancer patients-a nationwide cohort study. Int J Surg Mar. 2024;110(3):1519–26.
7. Agnelli G, Bolis G, Capussotti L, et al. A clinical outcome-based prospective study on venous thromboembolism after cancer surgery: the @RISTOS project. Ann Surg Jan. 2006;243(1):89–95.
8. Janczewski LM, Silver CM, Schlick CJR, et al. Association of pathologic factors with postoperative venous thromboembolism after gastrointestinal cancer surgery. J Gastrointest Surg Jun. 2024;28(6):813–9.
9. Xiang L, Jin S, Yu Y, et al. Risk of venous thromboembolism in patients undergoing gastric cancer surgery: a systematic review and meta-analysis. BMC Cancer Oct. 2023;23(1):933.
10. Wei Q, Wei ZQ, Jing CQ, et al. Incidence, prevention, risk factors, and prediction of venous thromboembolism in Chinese patients after colorectal cancer surgery: a prospective, multicenter cohort study. Int J Surg. 2023;109(10):3003–12.
11. Kim MH, Jun KW, Hwang JK, et al. Venous Thromboembolism Following Abdominal Cancer Surgery in the Korean Population: Incidence and Validation of a Risk Assessment Model. Ann Surg Oncol. 2019;26(12):4037–44.
12. Bahl V, Hu HM, Henke PK, et al. A validation study of a retrospective venous thromboembolism risk scoring method. Ann Surg Feb. 2010;251(2):344–50.
13. Caprini JA. Thrombosis risk assessment as a guide to quality patient care. Dis Mon Feb-Mar. 2005;51(2–3):70–8.

14. Gould MK, Garcia DA, Wren SM, et al. Prevention of VTE in nonorthopedic surgical patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;141(2 Suppl):eS227–77.
15. Patel SV, Liberman SA, Burgess PL, et al. The American Society of Colon and Rectal Surgeons Clinical Practice Guidelines for the Reduction of Venous Thromboembolic Disease in Colorectal Surgery. Dis Colon Rectum Sep. 2023;66(9):1162–73.
16. Key NS, Khorana AA, Kuderer NM, et al. Venous Thromboembolism Prophylaxis and Treatment in Patients With Cancer: ASCO Guideline Update. J Clin Oncol Jun. 2023;41(16):3063–71.
17. Pannucci CJ, Swistun L, MacDonald JK, et al. Individualized venous thromboembolism risk stratification using the 2005 Caprini score to identify the benefits and harms of chemoprophylaxis in surgical patients: a meta-analysis. Ann Surg. 2017;265(6):1094–103.
18. Klen J, Horvat M, Kozelj M, et al. Perioperative Prevention of Venous Thromboembolism in Abdominal Surgery Patients Based on the Caprini or the Padua Risk Score-A Single Centre Prospective Observational Study. Life (Basel). 2022;12(11):1843.
19. Lu X, Zeng W, Zhu L, et al. Application of the Caprini risk assessment model for deep vein thrombosis among patients undergoing laparoscopic surgery for colorectal cancer. Med (Baltim). 2021;100(4):e24479.
20. Zhang W, Sun R, Hu X, et al. Caprini risk assessment model combined with D-dimer to predict the occurrence of deep vein thrombosis and guide intervention after laparoscopic radical resection of colorectal cancer. World J Surg Oncol. 2023;21:299.
21. Yao J, Lang Y, Su H, et al. Construction of Risk Assessment Model for Venous Thromboembolism After Colorectal Cancer Surgery: A Chinese Single-Center Study. Clin Appl Thromb Hemost Feb. 2022;28:10760296211073748.
22. Zhou H, Jin Y, Chen G, et al. Predictive modeling of lower extreme deep vein thrombosis following radical gastrectomy for gastric cancer: based on multiple machine learning methods. Sci Rep Jul. 2024;14:15711.
23. Wu Y, Wang L, Yin Q, et al. Establishment and Validation of a Postoperative VTE Prediction Model in Patients with Colorectal Cancer Undergoing Radical Resection: CRSPOT Nomogram. Clin Appl Thromb Hemost. 2023;29:10760296231216966.
24. Anderson FA Jr, Wheeler HB, Goldberg RJ, et al. A population-based perspective of the hospital incidence and case-fatality rates of deep vein thrombosis and pulmonary embolism. The Worcester DVT Study. Arch Intern Med. May 1991;151(5):933–8.
25. Tsai AW, Cushman M, Rosamond WD, et al. Cardiovascular risk factors and venous thromboembolism incidence: the longitudinal investigation of thromboembolism etiology. Arch Intern Med. May 2002;162(10):1182–9.
26. Engbers MJ, van Hylckama Vlieg A, Rosendaal FR. Venous thrombosis in the elderly: incidence, risk factors and risk groups. J Thromb Haemost Oct. 2010;8(10):2105–12.

27. van Langevelde K, Sramek A, Rosendaal FR. The effect of aging on venous valves. Arterioscler Thromb Vasc Biol Oct. 2010;30(10):2075–80.
28. Favaloro EJ, Lippi G. Coagulation update: what's new in hemostasis testing? Thromb Res Jan. 2011;127(Suppl 2):S13–6.
29. Tripodi A, Chantarangkul V, Martinelli I, et al. A shortened activated partial thromboplastin time is associated with the risk of venous thromboembolism. Blood Dec. 2004;104(12):3631–4.
30. Weitz JI, Fredenburgh JC, Eikelboom JW. A Test in Context: D-Dimer. J Am Coll Cardiol Nov. 2017;70(19):2411–20.

Figures

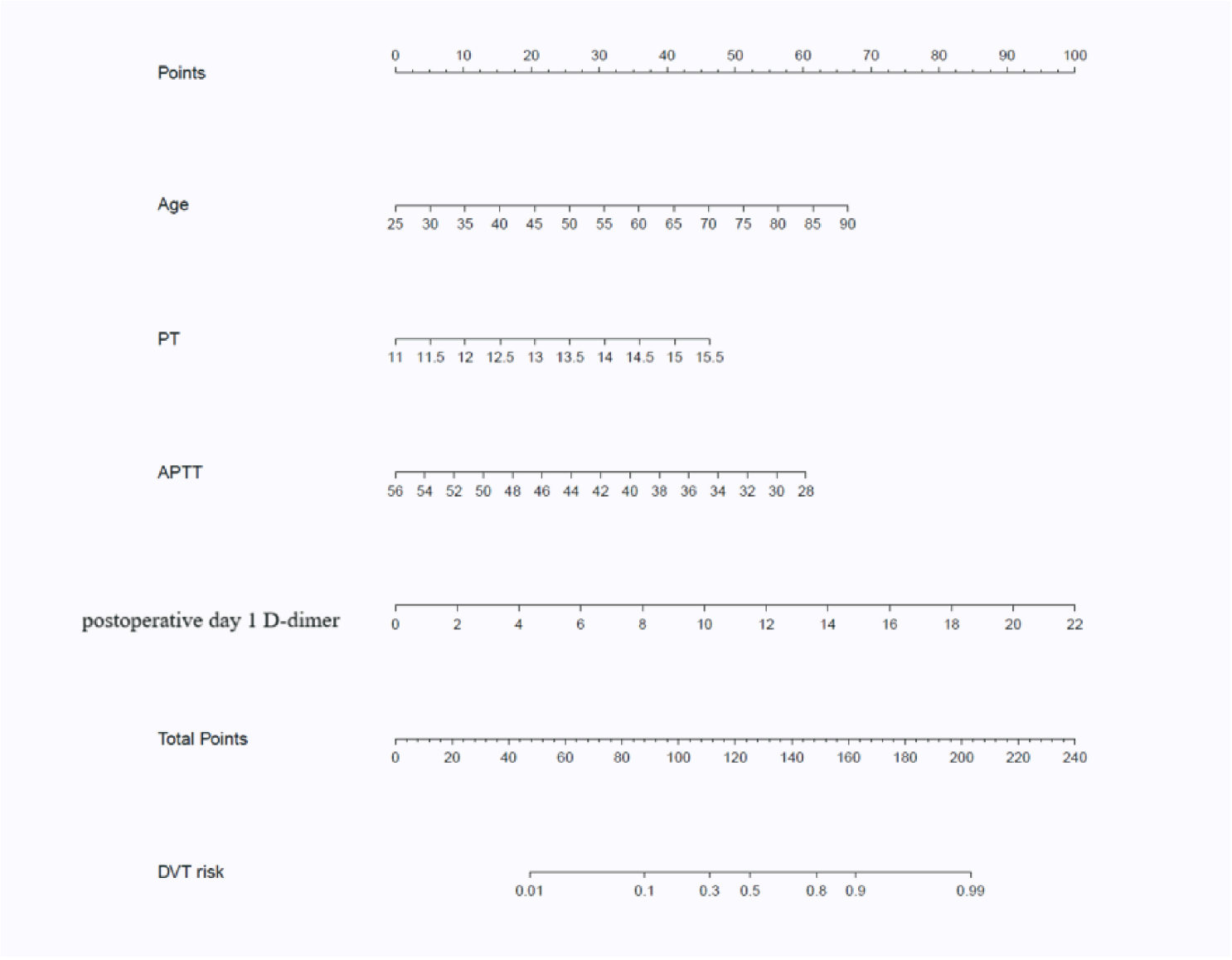


Figure 1

Nomogram for early postoperative risk stratification of lower extremity DVT in patients with gastric or colorectal cancers.

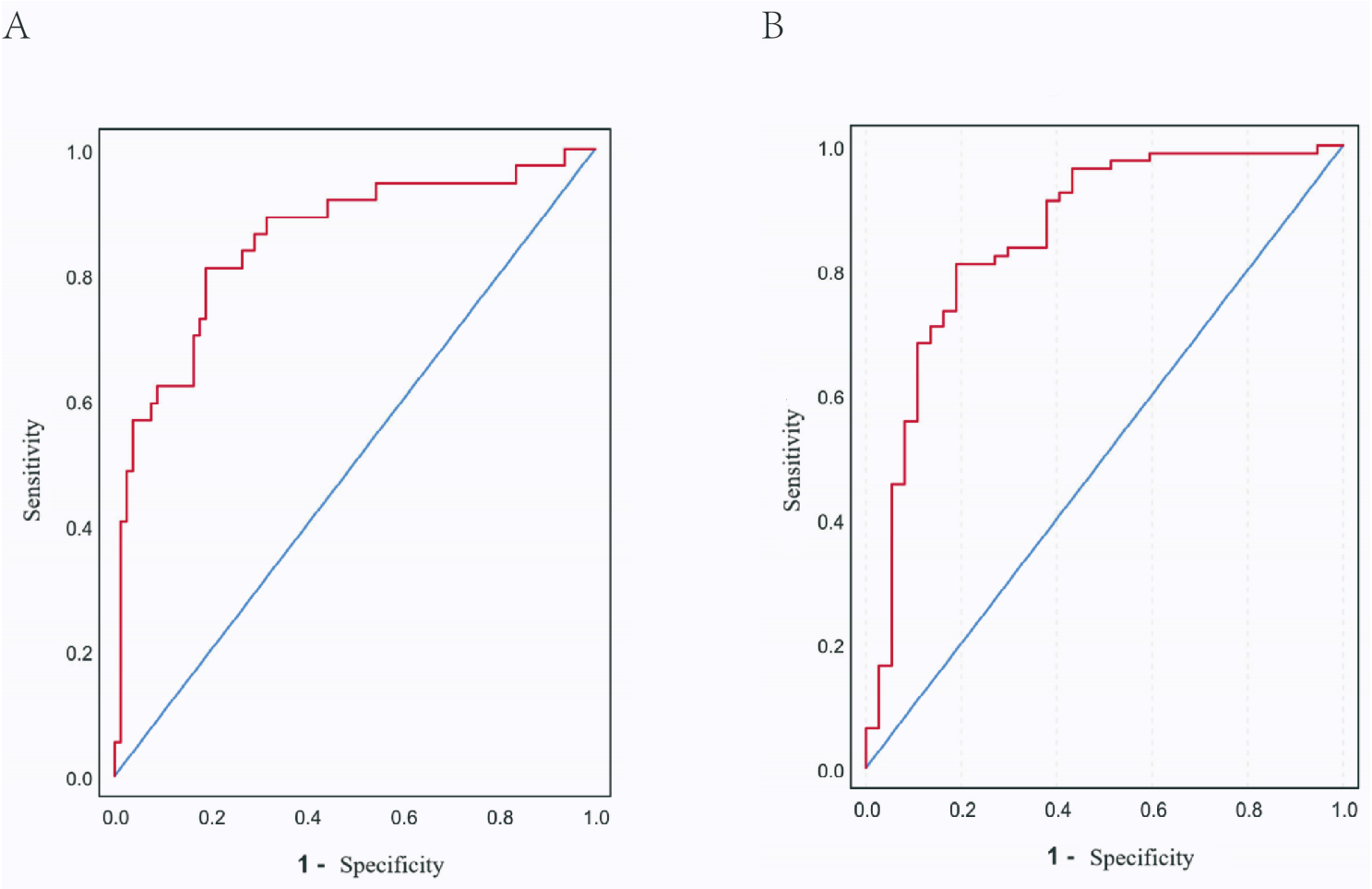


Figure 2

Receiver operating characteristic curves of the nomogram in the training cohort (A) and validation cohort (B).

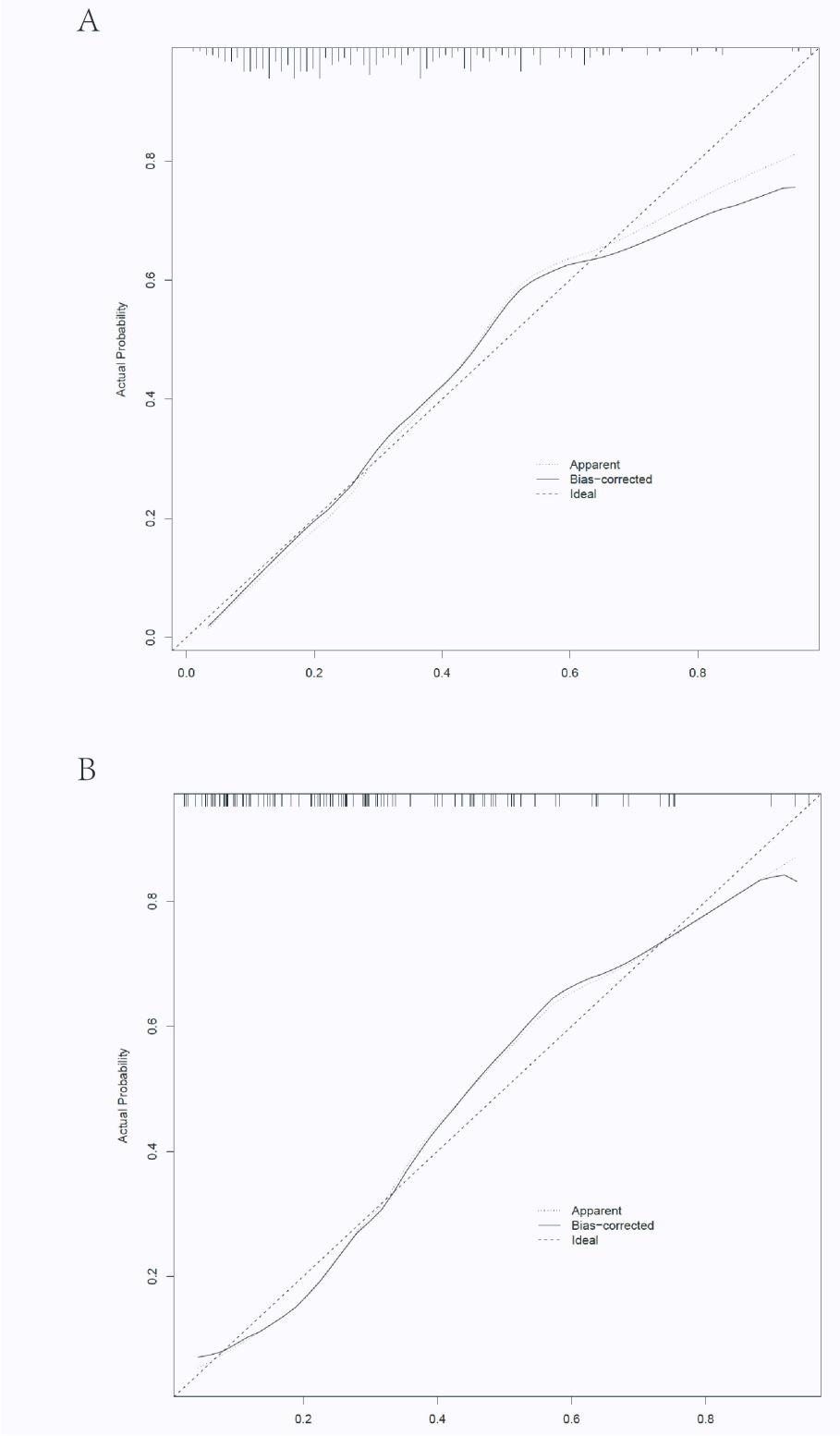


Figure 3

Calibration curves of the nomogram in the training cohort (A) and validation cohort (B).

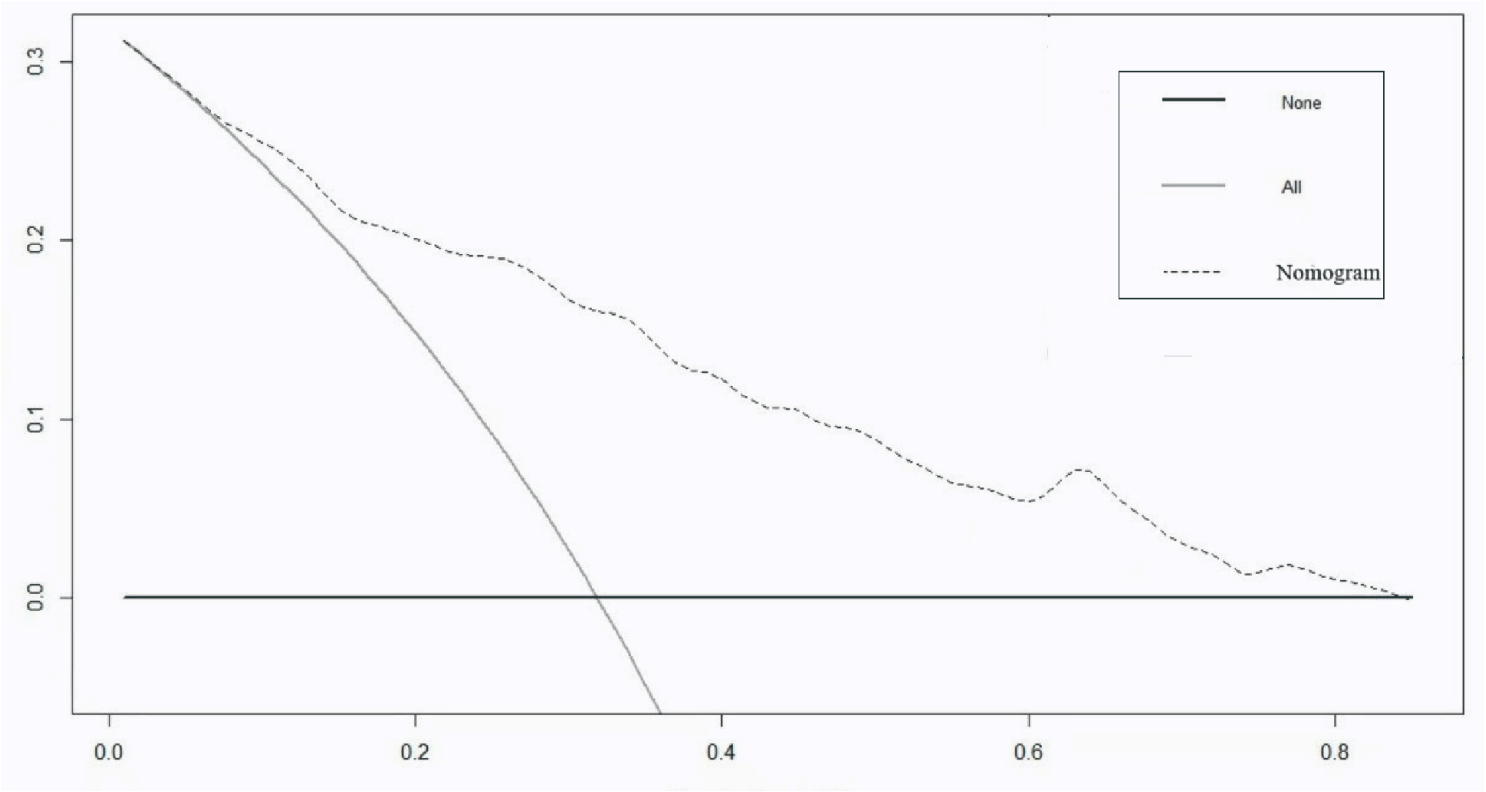


Figure 4

Decision curve analysis of the nomogram for early postoperative risk stratification of lower extremity DVT.