

Analysis of risk factors and construction of a prediction model for postoperative deep vein thrombosis in patients with periarticular knee fractures

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Abstract. The present study aimed to identify risk factors for postoperative deep vein thrombosis (DVT) in patients with periarticular knee fractures. A prediction model was constructed for the early identification of high-risk patients. Data from 319 patients at who underwent surgery at the Affiliated Hospital of Southwest Medical University (Luzhou, China) between January 2020 and December 2022 were analyzed. Based on ultrasound results, patients were divided into a DVT group (n=83) and a non-DVT group (n=236). Logistic regression was employed to identify independent risk factors. Subsequently, a nomogram model was established, which was validated via receiver operating characteristic curves, calibration curves and decision curve analysis (DCA). The DVT rate was 26.0%. Old age (OR, 1.0228), high American Society of Anesthesiologists grade (OR, 2.2764), greater blood loss (OR, 1.0015), blood transfusion (OR, 2.7917) and high D-dimer levels (OR, 1.0251) were identified as independent risk factors ($P<0.05$), while living in cities, high hemoglobin, high prealbumin, high Barthel index and high Braden scores served as protective factors ($P<0.05$). The model yielded an area under the curve value of 0.837. Additionally, the calibration curve showed high accuracy, and DCA validated the favorable clinical applicability of this predictive model. In conclusion, the model performs well in helping doctors to identify high-risk patients and optimize individualized therapeutic strategies.

Introduction

Deep vein thrombosis (DVT) remains one of the most notable perioperative complications in orthopedic trauma, with reported postoperative DVT incidence ranging from 15-30% among patients sustaining lower-extremity fractures; its secondary sequela, pulmonary embolism (PE), stands as a leading cause of sudden postoperative mortality, with fatal PE occurring in 0.5-2.0% of high-risk orthopedic-trauma cohorts (1,2). These conditions, collectively termed venous thromboembolism (VTE), impose a substantial burden on global healthcare systems (3). Among various orthopedic injuries, periarticular knee fractures, encompassing distal femoral and patellar, as well as proximal tibial and fibular fractures, represent a unique clinical challenge. These fractures are often induced by high-energy kinetic impacts and characterized by extensive localized vascular compromise and severe soft-tissue expansion (4,5). Furthermore, the mandatory rigid immobilization of the knee joint post-surgery markedly impedes the 'calf muscle pump' function, exposing this specific patient population to an exceptionally elevated risk for DVT (6).

The classic Virchow's Triad of stasis, endothelial injury and hypercoagulability remains the fundamental framework for understanding thrombus formation. However, the emerging concept of 'immunothrombosis' indicates that systemic inflammation triggered by skeletal trauma synergistically activates coagulation cascades, thereby complicating the predictive landscape (7,8). Despite extensive research and validated risk assessment scales for elective total joint arthroplasty, their generalizability to acute knee trauma is still limited (9,10). Trauma heterogeneity, characterized by variable surgical duration, intraoperative blood loss and injury-induced physiological stress, endows patients with knee fractures with a distinct risk profile that cannot be fully captured by single-parameter indicators, such as D-dimer or age (11,12).

In the era of precision medicine, clinical focus has shifted from generalized anticoagulation to individualized risk stratification. Building on existing clinical research, prediction models and biomarker-driven risk-stratification tools have been increasingly adopted across multiple specialties to identify high-risk subgroups and guide clinical management. For instance, predictive nomogram models have been constructed

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to recognize pathological upgrading risks among patients with low-grade squamous intraepithelial lesions following cervical conization, facilitating stratified clinical decision-making for heterogeneous premalignant lesions (13). Similarly, prognostic biomarkers and signaling-based prediction foundations for high-risk type I endometrial cancer have been explored via mechanistic investigations, confirming the clinical value of establishing risk-evaluation systems for disease progression (14). Both aforementioned studies have demonstrated the merits of integrating multi-dimensional clinical variables to build visualized nomogram-based risk-stratification tools. These endeavors inspire the present study focusing on orthopedic trauma-associated postoperative DVT. Although those two studies originated from gynecological disease settings, their individualized risk prediction frameworks are methodologically generalizable. These findings further support the necessity of establishing a dedicated nomogram for patients with periarticular knee fractures in the Southwest Chinese population. Despite the identification of isolated risk factors in sporadic studies, there is a conspicuous lack of a robust, integrated and visualized tool specifically tailored for the Southwest Chinese population, a demographic with a unique lifestyle and genetic background (15,16). Accordingly, nomograms, capable of integrating multiple variables into a simplified numerical graphical representation to calculate individualized event probabilities, have emerged as superior clinical decision-support tools (17,18).

Therefore, the present retrospective study analyzed clinical data from 319 patients with periarticular knee fractures treated at the Affiliated Hospital of Southwest Medical University (Luzhou, China). These efforts aimed to identify independent risk factors across multiple dimensions, including demographic characteristics, perioperative clinical features and laboratory biomarkers. By constructing and validating a visualized nomogram, supplemented by decision curve analysis (DCA), the study sought to provide a reliable scientific instrument for the early identification of high-risk individuals and the optimization of personalized thromboprophylaxis strategies.

Materials and methods

Patients. The clinical data of 319 patients with periarticular knee fractures were retrospectively reviewed. These patients underwent surgery at the Department of Orthopedic Trauma, Affiliated Hospital of Southwest Medical University, between January 2020 and December 2022. The patients were divided into two groups based on postoperative Doppler ultrasound results. The thrombus group included 83 patients with DVT, whereas the non-thrombus group comprised 236 DVT-free patients.

Inclusion and exclusion criteria. Patients included in this study were aged ≥ 18 years and presented with fresh, closed, single-limb fractures around the knee (distal femur, patella or proximal tibia/fibula). Two additional patients aged 14–17 years were identified during retrospective medical record curation; inclusion of these two adolescents was specially reviewed and approved by the Clinical Research Ethics Committee of the Affiliated Hospital of Southwest Medical University (Luzhou, China). The cutoff age of 14 years was adopted as

adolescent patients ≥ 14 years exhibit similar trauma patterns, surgical strategies and VTE risk profiles comparable to adult orthopedic trauma patients, and this cutoff was consistent with a previous trauma-related VTE study (19). These fractures occurred within 12 h prior to admission, with intact soft tissue conditions, and the interval from injury to surgery was < 3 weeks. Additionally, the admission ultrasound confirmed no pre-existing DVT. Meanwhile, the exclusion criteria were patients with open injuries, a pre-operative diagnosis of DVT, or high-risk infectious and severe metabolic diseases. Ultimately, those with incomplete electronic medical records or poor in-hospital clinical cooperation (inability to complete standardized inpatient examinations required for this retrospective study) were excluded from the analysis.

Observation indicators and data collection. Clinical data were collected from the electronic medical record system. Basic information included age (mean $\pm$ SD: 55.97 $\pm$ 16.61 years; range: 14–91 years), sex (188 men and 131 women), residence, BMI and smoking or drinking history were extracted; corresponding descriptive statistics are presented in Table I. Clinical features included fracture site, American Society of Anesthesiologists (ASA) grade, comorbidities, Barthel index (self-care-ability scale) and Braden score (pressure-ulcer-risk assessment scale) (20–22). Perioperative data included blood loss and blood transfusion, while laboratory indicators consisted of D-dimer, hemoglobin (Hb), prealbumin, fibrinogen, blood lipids and lymphocyte count. Perioperative pharmacological thromboprophylaxis was implemented according to local institutional guidelines for orthopedic trauma patients. However, given the retrospective study design, anticoagulant prophylaxis varied among enrolled patients in terms of specific type, dosage, initiation time and treatment duration. Individual regimens were tailored by attending surgeons according to the bleeding risk, comorbidities and laboratory test results of each patient.

Statistical analysis. Data analysis was conducted using IBM SPSS Statistics (version 26.0; IBM Corp.) and R software (version 4.5.2; R Core Team). SPSS was applied for descriptive statistics, univariate hypothesis testing, collinearity diagnostics and backward stepwise multivariate binary logistic regression. Results are presented in Tables I and II. Continuous variables were expressed as mean $\pm$ SD and compared via independent-sample t-tests, while categorical variables were presented as frequencies and percentages and compared using the χ^2 test or Fisher's exact test, where appropriate. Variables with $P < 0.05$ in the univariate analysis were screened as candidate independent variables. By contrast, those without statistical significance in univariate analysis were excluded from the multivariate regression model. Postoperative DVT was set as the dependent variable for subsequent regression modeling. Prior to constructing the multivariate logistic regression model, multicollinearity diagnostics were mandatory for all candidate predictors screened from univariate analysis ($P < 0.05$). The variance inflation factor (VIF) and tolerance statistic were calculated for multicollinearity quantification. A VIF value ≥ 5 paired with tolerance ≤ 0.2 was defined as substantial multicollinearity; variables meeting this threshold would be excluded or handled via clinical-driven variable selection or penalized regression. Only candidate variables without severe

Table I. Univariate analysis of risk factors for postoperative DVT in patients with fractures around the knee.

Variable	Total patients (n=319)	Non-DVT (n=236)	DVT (n=83)	P-value
Sex				0.160
Female	131 (41.1)	91 (38.6)	40 (48.2)	
Male	188 (58.9)	145 (61.4)	43 (51.8)	
Age, years	55.97±16.61	54.45±16.26	60.28±16.92	0.006
BMI, kg/m ²	22.63±2.79	22.76±2.88	22.25±2.51	0.149
Residence				0.025
Rural	145 (45.5)	98 (41.5)	47 (56.6)	
Urban	174 (54.5)	138 (58.5)	36 (43.4)	
Fracture site				0.072
Distal femoral fracture	143 (44.8)	99 (41.9)	44 (53.0)	
Patellar fracture	44 (13.8)	38 (16.1)	6 (7.2)	
Proximal tibiofibular fracture	132 (41.4)	99 (41.9)	33 (39.8)	
Smoking				0.742
Non-smoker	273 (85.6)	205 (86.9)	68 (81.9)	
Current smoker	46 (14.4)	31 (13.1)	15 (18.1)	
Alcohol consumption				0.800
Never drinker	277 (86.8)	206 (87.3)	71 (85.5)	
Current drinker	42 (13.2)	30 (12.7)	12 (14.5)	
Comorbid medical conditions				0.479
Absence of medical diseases	220 (69.0)	167 (70.8)	53 (63.9)	
Hypertension	59 (18.5)	39 (16.5)	20 (24.1)	
Diabetes mellitus	18 (5.6)	14 (5.9)	4 (4.8)	
Ischemic stroke	22 (6.9)	16 (6.8)	6 (7.2)	
ASA classification				<0.001
I	243 (76.2)	197 (83.5)	46 (55.4)	
II	56 (17.6)	26 (11.0)	30 (36.1)	
III	20 (6.3)	13 (5.5)	7 (8.4)	
Intraoperative blood loss	235.93±204.02	218.19±200.80	286.14±205.91	0.009
Intraoperative blood transfusion	49±15.4	27±11.4	22±26.5	0.002
Tourniquet use				0.110
Non-tourniquet group	174 (54.5)	122 (51.7)	52 (62.7)	
Tourniquet group	145 (45.5)	114 (48.3)	31 (37.3)	
D-dimer	7.56±11.97	6.58±12.28	10.28±10.66	0.016
Fibrinogen	3.50±1.59	3.45±1.61	3.65±1.53	0.341
Hemoglobin	124.79±20.48	128.30±19.14	114.81±20.98	<0.001
Prealbumin	224.12±62.83	232.29±61.34	200.89±61.55	<0.001
Cholesterol	4.29±1.09	4.33±1.09	4.16±1.10	0.216
Triglycerides	1.66±1.34	1.66±1.30	1.68±1.46	0.902
Lymphocyte count	1.33±0.60	1.37±0.57	1.24±0.68	0.082
Osteoporosis (X-ray or CT diagnosis)	143±44.8	101±42.8	42±50.6	0.271
Barthel index	44.87±11.28	46.19±11.15	41.14±10.89	<0.001
VTE (risk)	319±100.0	236±100.0	83±100.0	NA
Braden score	16.26±2.14	16.53±2.11	15.47±2.03	<0.001

Continuous variables are presented as mean ± SD and compared using an independent sample t-test. Categorical variables are expressed as n (%) and compared using the χ^2 or Fisher's exact test. P<0.05 was considered to indicate a statistically significant difference. Braden score: a scale used for pressure-ulcer-risk assessment; lower scores represent worse status. Barthel index: a self-care-ability assessment scale; higher scores indicate better functional independence. The row 'VTE (risk)' is a cohort descriptive row without group comparison.

multicollinearity (VIF <5) were retained and introduced into the backward stepwise multivariate binary logistic regression

model to calculate odds ratios (ORs), 95% confidence intervals (CIs), P-values, and regression coefficients. For continuous

Table II. Multivariate logistic regression analysis of risk factors for thrombosis in patients with knee fracture.

Variable	OR	95% CI	P-value
Age	1.0228	1.0063-1.0396	0.0065
Residence	0.5439	0.3281-0.9017	0.0182
ASA grade	2.2764	1.5209-3.4070	0.0001
Blood loss	1.0015	1.0004-1.0027	0.0098
Blood transfusion	2.7917	1.4853-5.2475	0.0014
D-dimer	1.0251	1.0030-1.0507	0.0270
Hemoglobin	0.9674	0.9548-0.9802	0.0010
Prealbumin	0.9915	0.9871-0.9958	0.0001
Barthel index	0.9577	0.9336-0.9809	0.0006
Braden score	0.7819	0.6889-0.8875	0.0001

A multivariate logistic regression model was constructed using a backward stepwise selection method. For continuous variables, OR represents the change in odds of postoperative DVT per one-unit increment of the corresponding variable. OR reflects odds rather than absolute disease probability and is not equivalent to relative risk. An OR >1 indicates a risk factor (positive association with DVT), while an OR <1 indicates a protective factor (negative association with DVT). The Barthel index and Braden score were assessed using the Barthel Index and Braden Scale, respectively. ASA, American Society of Anesthesiologists; OR, odds ratio.

predictors, the OR corresponded to the change in the odds of postoperative DVT per one-unit increment of the variable. An OR >1 indicated increased odds of DVT, whereas an OR <1 signified reduced odds of DVT. To facilitate quantitative clinical interpretation, the percentage change in odds was calculated as [(OR-1) x100%] for risk-increasing factors and [(1-OR) x100%] for protective factors. Notably, OR reflected odds rather than absolute disease probability and should not be directly interpreted as relative risk.

R software (version 4.5.2) was utilized for predictive model construction, model-performance assessment and the generation of all figures in the present study. Regression coefficients exported from SPSS were imported into R to establish the nomogram. Model discriminative ability was evaluated using the receiver operating characteristic (ROC) curve and the area under the curve (AUC). A calibration curve was used to assess consistency between predicted and observed DVT risks. DCA was performed to quantify the clinical net benefit of the prediction model. Core R packages included 'rms' for nomogram and calibration curve analysis (<https://CRAN.R-project.org/package=rms>), 'pROC' for ROC-AUC calculation (<https://CRAN.R-project.org/package=pROC>), 'rmda' for decision curve analysis (<https://CRAN.R-project.org/package=rmda>) and 'ggplot2' for figure visualization (<https://CRAN.R-project.org/package=ggplot2>). Two-sided P<0.05 was considered to indicate a statistically significant difference.

Results

Univariate analysis. The data from a total of 319 patients were analyzed. Among them, 83 patients developed DVT, yielding

an incidence rate of 26.0%. Univariate analysis showed significant differences between the DVT and non-DVT groups in several factors (Table I). Patients in the DVT group exhibited a higher mean age of 60.28±16.92 years compared with 54.45±16.26 years in the non-DVT group. High ASA classification (II and III), rural residence, greater intraoperative blood loss and intraoperative blood transfusion were further identified as associated with DVT. Furthermore, D-dimer concentrations were significantly elevated in the thrombosis group, whereas Hb and prealbumin levels were reduced. Finally, lower Barthel index scores and lower Braden score were also significantly associated with DVT. Notably, tourniquet use and lymphocyte count, two variables of particular clinical interest, did not differ significantly between groups on univariate analysis and were consequently excluded from the subsequent multivariate logistic regression analysis. Other non-significant variables in univariate analysis were also excluded and are listed in Table I.

Multivariate logistic regression analysis. A multivariate logistic regression analysis was performed to identify independent risk factors. Before fitting the multivariate model, multicollinearity assessment was conducted for all candidate variables retained from univariate screening. The VIF values of these predictors ranged from 1.05 to 2.38, with corresponding tolerance statistics varying between 0.420 and 0.952. All variables satisfied VIF <5 and tolerance >0.2 (mean VIF, 1.46), demonstrating no substantial multicollinearity among the input predictors. Accordingly, all candidate variables were considered eligible for inclusion in the multivariate logistic regression. The percentage change presented below reflected the relative change in the odds of postoperative DVT rather than absolute-risk disparities. Multivariate outputs indicated that age (OR, 1.0228), higher ASA grade (OR, 2.2764), increased intraoperative blood loss (OR, 1.0015) and blood transfusion (OR, 2.7917) and D-dimer (OR, 1.0251) constituted significant risk factors for DVT development (Table II).

Quantitatively, each 1-year increase in age was associated with a 0.15% increase in the odds of DVT (Table II). Each 1-ml increment in intraoperative blood loss corresponded to a 0.15% rise in DVT odds and each one-unit elevation of D-dimer increased the odds of DVT by 2.51%. Intraoperative blood transfusion raised the odds of DVT by 179.17%, and each one-grade elevation in ASA grade yielded a 127.64% increase in DVT odds.

By contrast, urban residence (OR, 0.5439), higher Hb (OR, 0.9674), increased prealbumin (OR, 0.9915), higher Barthel index (OR, 0.9577) and Braden score (OR, 0.7819) acted as protective factors associated with reduced DVT odds. Each 1-g/l increase in Hb was linked to a 3.26% reduction in DVT odds, while each one-unit rise in prealbumin decreased DVT odds by 0.85%. Each one-point increase in the Barthel index lowered DVT odds by 4.23%, while each one-point elevation in the Braden score corresponded to a 21.81% drop in DVT odds. Living in urban areas was associated with a 45.61% reduction in the odds of postoperative DVT.

Construction, visualization and clinical interpretation of the risk prediction nomogram. To translate the multivariable regression equation into a practical and intuitive

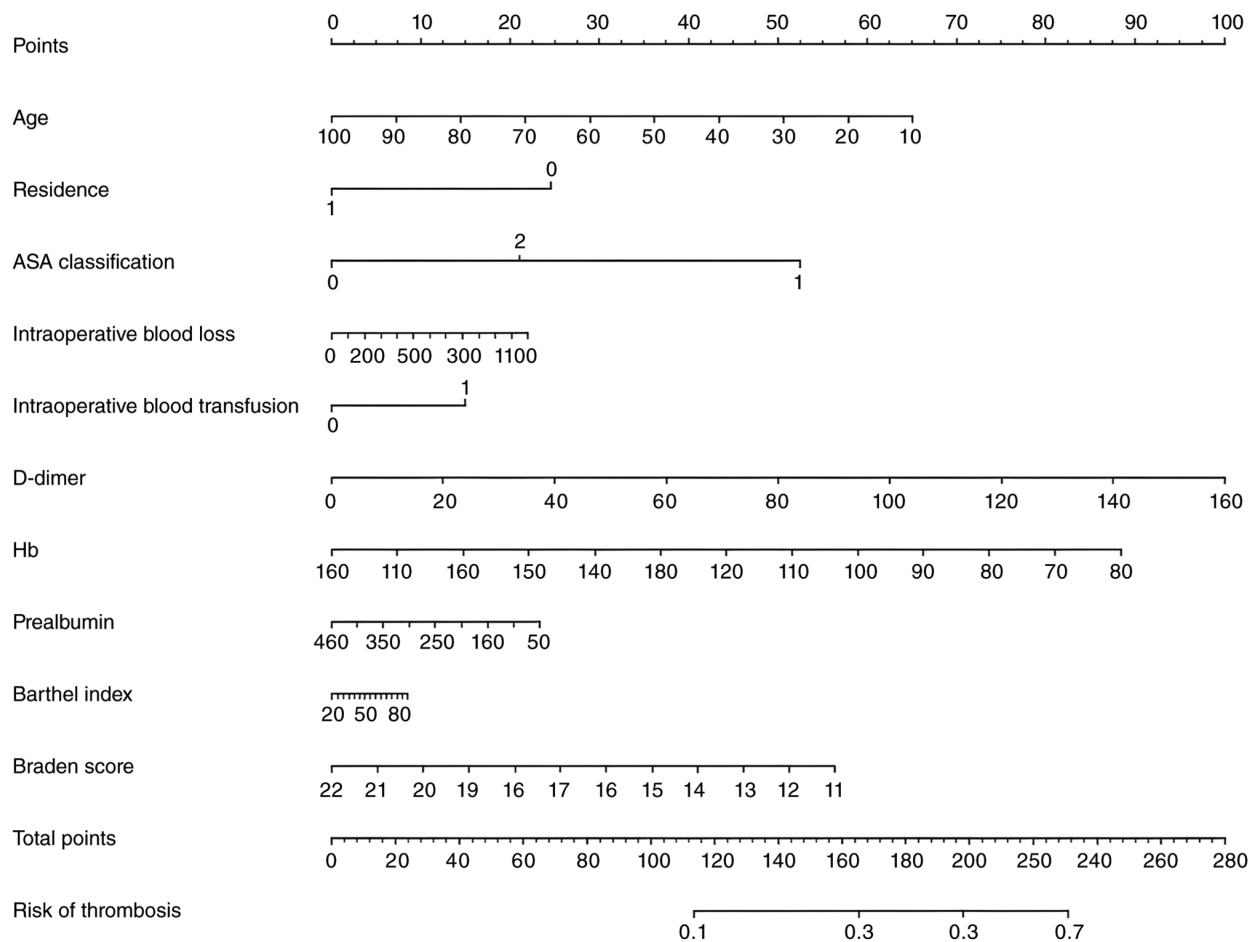


Figure 1. Nomogram for predicting the individualized risk of postoperative DVT in patients with periarticular knee fractures. Instructions for clinical workflow and scoring: Locate the patient's individual clinical parameter value on each corresponding variable axis (age, residence, ASA grade, intraoperative blood loss, blood transfusion, D-dimer, Hb, prealbumin, Barthel index and Braden score). Draw a vertical line upward from each variable position to the top-most 'Points' scale to determine the specific points assigned to each indicator. Calculate the sum of points across all 10 indicators to establish the aggregate score on the 'Total Points' axis. Draw a vertical line downward from the identified total points to the bottom 'Risk of thrombosis' axis to read the patient's individualized postoperative DVT risk percentage, which subsequently guides tri-tier prophylactic decision-making (low, intermediate or high risk). Hb, hemoglobin; DVT, deep vein thrombosis; ASA, American Society of Anesthesiologists.

bedside decision-support tool, an individualized risk prediction nomogram integrating the 10 independent predictors was constructed (Fig. 1). In this nomogram, each clinical predictor corresponded to an axis with scaled values, and an individual point was assigned by drawing a vertical line upward from the patient's value to the topmost 'Points' scale (ranging from 0 to 100 points). The points corresponding to all 10 variables were summed to obtain an aggregated score on the 'Total Points' axis. Finally, a vertical line dropped from this total score to the 'Risk of Thrombosis' axis then yielded the patient-specific predicted probability of postoperative DVT.

Clinical example illustration. A 65-year-old rural resident (ASA grade III; admission D-dimer, 8.5 mg/l; Hb, 95 g/l; prealbumin, 180 mg/l; Barthel index, 45; Braden score, 14) was taken as a representative example. The patient had undergone open reduction and internal fixation with 350 ml of intraoperative blood loss and received intraoperative blood transfusion. By mapping each indicator onto the nomogram, the respective variable scores were obtained and summed, yielding a total point score of ~178 points. Projecting this aggregate

score downward to the probability axis revealed an estimated postoperative DVT risk of roughly 68.5%, unambiguously categorizing this patient into the high-risk cohort warranting proactive perioperative intervention.

Discriminative performance and ROC/AUC analysis. Discriminative power of the prediction nomogram was evaluated using ROC curve analysis (Fig. 2). The AUC reached 0.837 (95% CI, 0.790-0.880; bootstrap-corrected 95% CI, 0.782-0.918), which validated the robust discriminative capability of the established multifactorial model in distinguishing periarticular knee fracture patients who developed postoperative DVT from those who did not, substantially outperforming single-variable assessments.

Model calibration and goodness-of-fit. To assess the agreement between predicted probabilities and actual clinical outcomes, model calibration was evaluated by plotting a calibration curve with 1,000 bootstrap resamplings ($n=313$) (Fig. 3). The bias-corrected solid line closely mirrored the ideal 45-degree reference diagonal across the entire range of risk probabilities. The model achieved a mean absolute error of 0.019, reflecting

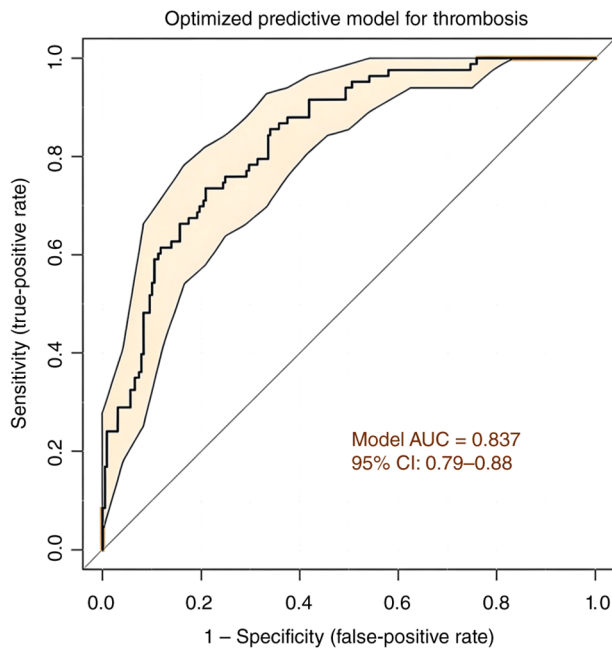


Figure 2. Receiver operating characteristic curve of the predictive model for postoperative thrombosis. The green solid line represents the performance of the model in predicting deep vein thrombosis in patients with periarticular knee fractures. The AUC is 0.837 (95% CI, 0.782-0.918), indicating the good discriminative ability of the model. The diagonal line represents the performance of a chance-level classifier (AUC, 0.50). AUC, area under the curve; CI, confidence interval.

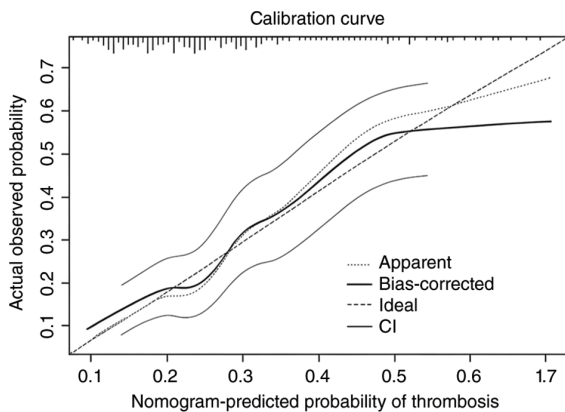


Figure 3. Calibration curve of the predictive model for postoperative thrombosis. The x-axis represents the predicted probability of deep vein thrombosis, and the y-axis represents the actual observed probability. The dashed line represents an ideal prediction where the predicted and observed probabilities are identical. The solid line represents the performance of the model corrected for bias using 1,000 bootstrap repetitions ($n=313$). The mean absolute error of 0.019 indicates excellent agreement between the predicted and observed outcomes. CI, confidence limits.

favorable goodness-of-fit and negligible overfitting in internal risk estimation.

DCA and clinical utility. DCA was performed for the nomogram across varying threshold probabilities (Fig. 4). Within a broad threshold probability range (0.10-0.60), the prediction model delivered markedly higher standardized net benefit than the ‘treat-all’ strategy (universal intensified thromboprophylaxis) and the ‘treat-none’ strategy (routine non-intensified

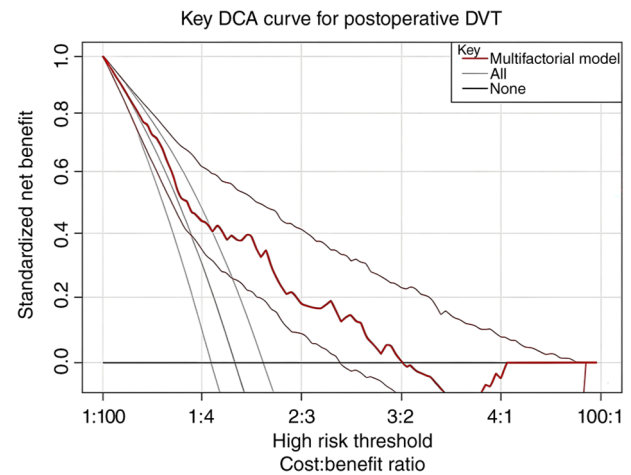


Figure 4. DCA for the postoperative thrombosis prediction model. The y-axis measures the net benefit. The red solid line represents the predictive model, the blue line represents the strategy of treating all patients (All), and the horizontal dashed line represents the strategy of treating no patients (None). Within a wide range of threshold probabilities (0.1 to 0.6), the model provides a higher net benefit compared to both the ‘treat-all’ and ‘treat-none’ strategies, indicating its clinical utility for guiding deep vein thrombosis prevention in patients with periarticular knee fractures. DCA, decision curve analysis.

management). These findings confirmed the substantial clinical utility of the nomogram for risk stratification in routine surgical practice.

Discussion

The present study retrospectively analyzed the clinical data of 319 patients with periarticular knee fractures, aiming to construct and internally validate a visual nomogram-based prediction model. The established nomogram could effectively predict the risk of postoperative DVT. Results showed a postoperative DVT incidence of 26.0%, consistent with the high-risk level reported in recent studies (23-25). Periarticular knee fractures were mainly caused by high-energy trauma, which could lead to severe damage of local vascular endothelium; they may also cause extensive soft-tissue contusion. Compulsory knee immobilization should be performed after surgery. This condition impairs the function of the calf muscle pump, slowing down venous blood flow. All these factors raise the basic risk of DVT occurrence (26).

Multivariate logistic regression analysis was conducted in the present study. Ultimately, a total of 10 independent influencing factors were identified. These factors included age, residential area, ASA physical status classification, intraoperative blood loss, intraoperative blood transfusion, D-dimer, Hb, prealbumin, Barthel index and Braden score. The nomogram model was established based on these variables. The ROC curve of this model was 0.837 (95% CI, 0.79-0.88). The calibration curve showed favorable consistency between predicted probability and actual observed frequency. DCA further confirmed the excellent net clinical benefits of this model. These findings validated the discrimination, calibration and clinical value of the established nomogram model for predicting the postoperative DVT risk in patients with periarticular knee fractures.

Age was identified as an independent risk factor for DVT (OR, 1.0228; $P=0.0065$). The mean age was 60.28 ± 16.92 years

in the thrombosis group. Each one-year increment in age was associated with a 2.28% increase in the odds of DVT. Aging promotes prothrombotic alterations in human coagulation function, accompanied by impaired vascular endothelial function and reduced fibrinolytic activity. Additionally, elderly patients commonly present with multiple comorbidities and diminished physical activity, collectively contributing to a substantially elevated risk of DVT (27).

ASA classification could evaluate the overall preoperative health status of patients and demonstrated a strong link with DVT risk in the present research (OR, 2.2764; $P=0.0001$). ASA grade I accounted for 55.4% of patients in the DVT group, whereas an 83.5% proportion was identified in the non-DVT group. The DVT group comprised more patients with ASA grade II and above. Each one-grade elevation in ASA grade contributed to a 127.64% increase in the odds of DVT, with a higher ASA grade indicating severe underlying diseases or poor general physical condition. These patients exhibit diminished compensation ability in response to trauma and surgical stress, accompanied by pronounced inflammatory responses, which further aggravates the hypercoagulable state of the blood (28).

D-dimer is a sensitive marker that reflects the activation of the fibrinolytic system. In the present study, it was considered an independent risk factor for DVT (OR, 1.0251; $P=0.0270$). The D-dimer level was 10.28 ± 10.66 mg/l in the DVT group, which was significantly higher than the 6.58 ± 12.28 mg/l in the non-DVT group. Each one-unit increase in D-dimer elevated the odds of DVT by 2.51%. Increased D-dimer levels indicate active thrombosis and secondary fibrinolysis in the body. Its dynamic changes facilitate the identification of early DVT (29).

The present study observed clear associations between intraoperative blood loss, intraoperative transfusion and DVT odds. Intraoperative blood loss (OR, 1.0015; $P=0.0098$ and intraoperative blood transfusion (OR, 2.7917; $P=0.0014$) were both identified as independent risk factors. While each 1-ml increase in intraoperative blood loss only raised the odds of DVT by 0.15%, large cumulative blood loss could yield clinically meaningful elevation in DVT odds. Intraoperative blood transfusion increased the odds of DVT by 179.17%. Furthermore, massive intraoperative blood loss triggers the thrombosis-inflammation cascade reaction, which promotes tissue factor release and platelet activation, while also activating the human coagulation system (30). Banked blood reduces red blood cell deformability during transfusion, causing micro-circulation disorders. Transfusion-related immunomodulation releases pro-inflammatory cytokines, and these substances further accelerate thrombosis (31). Doctors should closely monitor DVT risk among patients with substantial intraoperative blood loss or those receiving intraoperative transfusion and reinforce perioperative anticoagulation management for this high-risk patient subgroup (32).

Hb and prealbumin served as independent protective factors in this present study. The odds of DVT decreased by ~3.26% with every 1 g/l increase in Hb (OR, 0.9674; $P=0.0010$), with low Hb levels suggesting anemia. Anemia could affect tissue oxygen supply, change blood viscosity and slow blood flow. These effects raise the risk of venous stasis (33). Prealbumin could reflect nutritional status and acute phase reactions and showed a protective effect against DVT in the present study

(OR, 0.9915; $P=0.0001$). Each one-unit rise in prealbumin reduced the odds of DVT by 0.85%, with low prealbumin levels indicating malnutrition or severe stress in patients. These patients may exhibit poor general conditions and slow postoperative recovery, necessitating long-term bed rest, which could itself increase the risk of DVT (34). Functional assessment indexes demonstrated critical connections with DVT risk in the present study. The odds of DVT decreased by ~4.23% with every one-point increase in the Barthel index (OR, 0.9577; $P=0.0006$), with a higher Barthel index indicating enhanced basic physical activity. These patients could get out of bed early after surgery. Early ambulation may serve as a key measure to prevent DVT (35). The Braden score was also an independent protective factor; each 1-point higher for the Braden score reduced the odds of DVT by 21.81% (OR, 0.7819; $P=0.0001$). Patients with low Braden scores often stay in bed for a long time and have limited physical movement. These situations slow the venous blood flow of patients while increasing the risk of thrombosis (36). DVT prevention should not only rely on drug anticoagulation, and doctors should also prioritize early rehabilitation training and standardized nursing care.

Residential area represents a social demographic factor. Within the present study, it exhibited an independent association with DVT risk (OR, 0.5439; $P=0.0182$). Living in urban areas was associated with a 45.61% reduction in the odds of postoperative DVT. The DVT incidence was 56.4% in rural patients and 41.5% in their urban counterparts. This difference relates to multiple aspects, including timely medical treatment, health literacy, postoperative rehabilitation conditions and family nursing support (37). The social background of patients should also be taken into account when assessing the DVT risk, and more attention should be given to rural patients with limited medical resources.

Notably, existing Chinese real-world and cohort studies have reported inconsistent findings regarding the correlation between residential location and postoperative venous thromboembolism risk, especially for populations from Southwest China (38,39). Some regional orthopedic cohort studies support the present observation that rural patients exhibit higher DVT risk after trauma-related surgery, which may be attributable to disparities in preoperative health-seeking behavior, access to standardized postoperative rehabilitation guidance and family-based nursing resources (40). However, several other domestic VTE epidemiological investigations fail to identify residential area as an independent risk factor for perioperative DVT after orthopedic trauma; those studies suggest that urban-rural differences may be confounded by age, comorbidity burden and surgical characteristics rather than representing an independent effect (41). The discrepancy across studies may partly stem from regional socioeconomic variation, differences in case-mix, single-center sampling features and variable adjustment sets for confounding variables. In the present study, for the Southwest Chinese population, residential area remained statistically significant after adjusting for demographic, laboratory and peri-operative covariates. This implied that social-demographic context could not be ignored when performing DVT risk stratification in this specific population. Nevertheless, considering conflicting evidence from published cohorts, further multi-center data

should still be acquired for the external validation of such an association.

The established nomogram model combined the aforementioned 10 independent factors into a visual scoring tool. Internal verification confirmed its favorable discrimination, with an AUC of 0.837. The calibration curve showed high-level consistency between predicted and actual values, while the DCA curve confirmed that the model yielded superior net clinical benefits. Relative to universal intervention and non-intervention strategies, this predictive model exhibited better clinical application value and showed enhanced promise for clinical decision making (42).

A total of two previous studies have demonstrated the feasibility of developing visualized risk-stratification tools for gynecological disease cohorts, which provide important methodological references for our present work. Peng *et al* (13) constructed a nomogram model to predict the risk of pathological upgrading after cervical conization in patients with low-grade squamous intraepithelial lesions, confirming the superior predictive performance of a multi-variable-integrated nomogram over single-indicator assessment (AUC, 0.744). This gynecological retrospective study shared similar statistical workflows with the present study, including univariate-multivariate logistic regression, internal validation via bootstrap resampling, calibration curve analysis and DCA evaluation, yet its research object was cervical precancerous lesion rather than orthopedic trauma-related thrombotic events. He *et al* (14) explored the L1CAM-PTK2-FAK-GRB2-SOS-RAS signaling axis in type I high-risk endometrial cancer and highlighted the clinical necessity of building risk-evaluation systems for tumor progression, although the work focused on molecular experimental mechanisms instead of clinical retrospective prediction modeling. Compared with these two gynecological-focused studies, the present nomogram targeted postoperative DVT among southwest Chinese patients with periarticular knee fractures. Beyond conventional demographic, peri-operative and laboratory variables, the study further incorporated functional status indicators including the Barthel index and Braden score into risk predictors. Moreover, DCA was strictly performed to quantify clinical net benefit, which strengthened the real-world practicability of the model for trauma-patient risk stratification. Collectively, these published gynecological studies inspire the methodological design of the present study; however, the present model expands the application scenario of visualized nomogram-based risk-prediction from gynecological oncology to orthopedic trauma venous thromboembolism.

The present study has several advantages compared with previous prediction models for lower limb fracture patients (43). First, the focus was specifically on patients with periarticular knee fractures, a subgroup with distinctly elevated DVT risk owing to mandatory postoperative knee immobilization, whereas most existing nomograms targeted general lower-limb fractures or hip-fracture populations. Second, beyond conventional demographic, perioperative and laboratory biomarkers, the present study incorporated functional-status indicators, including the Barthel index and Braden score. This design followed the bio-psycho-social medical model and integrated physical function and nursing-related risk into risk stratification. Third, DCA was adopted to quantify net clinical

benefits rather than merely reporting AUC and calibration performance, providing evidence for real-world clinical utility.

Direct comparisons with previously published DVT prediction models for orthopedic trauma revealed pronounced differences in predictor composition and target population. Multiple existing nomograms for lower-limb fracture-related DVT were developed for mixed fracture types or geriatric hip-fracture cohorts (44,45) and few prediction tools were tailored exclusively for patients with periarticular knee fractures (46-48). Some earlier models relied heavily on laboratory markers such as D-dimer alone; however, this could be frequently elevated after trauma regardless of actual thrombus formation. Its standalone discriminatory power in acutely injured patients is thus severely limited. Other published prediction tools did not incorporate functional evaluation indicators, ignoring the contribution of postoperative mobility and long-term bed-rest risk to thrombogenesis. However, the present proposed nomogram synthesized demographic features, perioperative variables, laboratory biomarkers and functional scales, effectively facilitating more comprehensive individualized risk assessment.

Most previously established nomograms for DVT following orthopedic trauma only reported discrimination (AUC) and calibration performance, while omitting DCA-based net-benefit evaluation, which restricted judgement on their real-world clinical value (49,50). Various competing prediction tools also suffered from limited external validation, as they were built on single-center datasets without stratified functional-status indicators (44,51). Notably, the present nomogram was considered only applicable for adult and adolescent patients ≥ 14 years with closed periarticular knee fractures admitted to tertiary-level hospitals in Southwest China. Direct extrapolation to patients with open fractures, those with pre-existing venous thrombosis or pediatric populations < 14 years is not recommended.

From a clinical implementation perspective, this visualized nomogram could facilitate standardized risk-oriented management for patients with periarticular knee fractures.

To overcome the barrier between statistical modeling and real-world clinical application, a standardized, step-by-step clinical workflow was proposed for integrating this nomogram into routine trauma care pathways: Step 1 consists of multi-dimensional data collection at admission and surgery. Upon admission and immediately following definitive surgical fixation, clinicians and trauma nurses should routinely retrieve the 10 candidate parameters from the electronic health record (EHR). These include demographic variables (age and residence), baseline physiological/nursing scales (ASA classification, admission Barthel index and Braden score), baseline laboratory indicators (admission D-dimer, Hb and prealbumin levels) and surgical records (intraoperative blood loss and blood transfusion status).

Step 2 consists of individualized nomogram point calculation and risk derivation. During postoperative rounds or multidisciplinary team trauma meetings, the attending surgeon should locate each parameter on the nomogram axis, compute the cumulative point score and project it downward to determine the exact individualized probability of postoperative DVT. Notably, the nomogram output yields predictive risk probability rather than definitive diagnosis. Therefore,

nomogram results should not substitute clinical judgment and auxiliary imaging examinations.

Step 3 consists of tri-tier risk stratification and tailored thromboprophylaxis protocols. Based on the derived probability and DCA-supported threshold windows, patients were categorized into three risk tiers to guide shared decision-making: i) Low-risk tier (predicted probability <15%), including standard baseline mechanical prophylaxis (graduated compression stockings or early ankle-pump exercises) combined with routine low-dose pharmacological anticoagulation, thereby minimizing unnecessary drug escalation and mitigating excessive bleeding risks; ii) intermediate-risk tier (predicted probability 15-40%), including standard weight-adjusted pharmacological thromboprophylaxis (for example, standard-dose low-molecular-weight heparin or direct oral anticoagulants) combined with continuous intermittent pneumatic compression devices and nurse-assisted early bed-side mobilization within 24-48 h postoperatively; and iii) high-risk tier (predicted probability >40%), including intensified multimodal prophylaxis, such as enhanced surveillance via bedside bilateral lower-limb Doppler ultrasound on postoperative days 3 and 7, early consultation with hematology/vascular surgery, optimization of nutritional support to correct hypoprealbuminemia, dynamic Hb monitoring and consideration of extending pharmacological thromboprophylaxis post-discharge for 14-35 days.

Step 4 consists of continuous evaluation and transition to digitalized EHR tools. Despite the feasibility of manual point calculation using the printed nomogram, prospective clinical implementation would be considerably accelerated by embedding this mathematical formula as an automated digital calculator within hospital information systems, allowing instantaneous automated risk output upon EHR data entry.

Nevertheless, several practical obstacles should be still noted for onsite deployment. Manual scoring of the paper-based nomogram remains time-consuming for busy trauma wards, making digital transformation necessarily important for its widespread bedside application.

It should also be emphasized that the present model was built on data from a single tertiary center in Southwest China. Prior to extensive clinical promotion, external validation across multi-center cohorts from diverse geographic and medical-level institutions should be performed to confirm its generalizability. To validate its superior or comparable discrimination and calibration performance relative to alternative risk-stratification tools, direct head-to-head external comparison against existing published prediction models should be performed in future prospective studies.

Certain limitations of this study should still be acknowledged. First, it was a single-center retrospective study with limited sample source, likely inducing selection bias. Multi-center prospective studies should be conducted to confirm the general application of the results. Second, color Doppler ultrasound with low sensitivity for distal DVT was used for the DVT diagnosis. Some asymptomatic distal DVT cases might be overlooked, thereby underestimating the true incidence of venous thromboembolism. Third, only static biomarkers at admission were detected, and the dynamic changes of perioperative indexes were not observed. Dynamic monitoring would improve the accuracy of DVT prediction.

Fourth, some potential confounding factors, including specific anticoagulation protocols and hereditary thrombophilia gene mutations, were not fully controlled due to medical record restrictions. Future studies should focus on dynamic biomarker detection, and genomics and proteomics data could be integrated. These methods could facilitate the construction of more accurate individualized risk prediction models.

Despite the clinical utility and robust performance of the proposed nomogram, several limitations should be acknowledged. First, the present single-center retrospective study was performed at one tertiary medical center in Southwest China, which introduced inherent selection bias and restricted regional generalizability. Despite internal validation demonstrating good discrimination and calibration, external validation in cohorts from different geographic regions and medical centers is required to determine broader applicability. Second, the present DVT diagnosis depended on Doppler ultrasound. While this method is noninvasive and convenient, its sensitivity for distal or asymptomatic calf muscular vein thrombosis varies, which may slightly underestimate the true incidence of subclinical VTE. Third, laboratory biomarkers including D-dimer, hemoglobin and prealbumin were only measured once at admission. The present study did not capture perioperative dynamic changes of these indicators, which may provide further insight into real-time thrombogenesis. Fourth, a number of granular clinical variables were missing from the retrospective electronic medical records, such as the exact intraoperative knee flexion angle, detailed post-discharge thromboprophylaxis protocols and inherited thrombophilia status. In addition, perioperative anticoagulation regimens were individualized by attending surgeons rather than standardized, an unmeasured confounding factor that may affect postoperative DVT outcomes.

Future concrete research directions were thus proposed as follows: i) Conduct multi-center prospective cohorts from different geographic regions of China for external validation of this nomogram model; ii) incorporate dynamic peri-operative laboratory biomarker monitoring to improve risk prediction performance; iii) integrate clinical data with multi-omics data to explore novel thrombotic risk markers for patients with knee periarticular fractures; and iv) develop HER-embedded automated risk-calculator tools to facilitate real-world clinical application of this prediction nomogram.

In conclusion, patients with periarticular knee fractures are at a high risk of postoperative DVT, which arises from the combined effects of multiple clinical factors. The present study developed and verified a novel nomogram model that encompassed clinical features, laboratory indicators and functional evaluation data. This model could accurately identify high-risk patients and provide quantitative evidence for the formulation of individualized prevention plans. Clinicians should adopt active DVT prevention measures for specific patients, including elderly individuals and those with high ASA grades, large intraoperative blood loss, intraoperative transfusion, elevated D-dimer, anemia, low prealbumin, low Barthel index and low Braden score. Further multi-center prospective studies should be conducted for constant optimization, and its practical application in clinical decision support systems should be continuously explored.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

JL and SL contributed equally to the present study. JL and YY conceived and designed the research protocol and analytical framework of the present nomogram study. JL, SD and GL completed systematic literature retrieval, screening and evidence summary. SL was responsible for clinical case screening, inclusion and exclusion verification, follow-up data collation and clinical outcome interpretation of enrolled patients with knee periarticular fractures. JL completed data sorting, statistical model construction, predictive performance verification and relevant result analysis. JL and GL participated in raw data acquisition, collation and preliminary interpretation of analytical results. JL drafted the original manuscript. YY performed critical revision and academic supervision of the manuscript. SD participated in study design optimization, checked the integrity of clinical data and revised key intellectual content of the manuscript. All authors read and approved the final version of the manuscript, participated in the critical revision of the manuscript and agreed to be accountable for all aspects of the work to ensure the accuracy and integrity of the research. JL and SL confirm the authenticity of all the raw data.

Ethics approval and consent to participate

The present retrospective study was approved by the Clinical Research Ethics Committee of the Affiliated Hospital, Southwest Medical University (approval no. KY2026197; approval date, 27 March 2026). The study was based on de-identified archived electronic medical records. Prior to study initiation, the Ethics Committee granted a waiver of signed informed consent for all participants in accordance with Article 38 of the 'Measures for the Ethical Review of Biomedical Research Involving Human Beings'. Although the original study protocol intended to enroll patients aged ≥ 18 years, two adolescent participants aged 14–17 years were identified during retrospective data curation. The Ethics Committee specifically reviewed the cases of these two minor subjects and approved the waiver of guardian informed consent, considering that no additional research-related interventions were performed and the historical patients could not be traced. This research was performed in accordance with the Declaration of Helsinki.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. Prisco D, Tufano A, Cenci C, Pignatelli P, Santilli F, Di Minno G and Perticone F: Position paper of the Italian society of internal medicine (SIMI) on prophylaxis and treatment of venous thromboembolism in patients with cancer. *Intern Emerg Med* 14: 21-38, 2018.
2. Geerts WH, Pineo GF, Heit JA, Bergqvist D, Lassen MR, Colwell CW and Ray JG: Prevention of venous thromboembolism: The Seventh ACCP conference on antithrombotic and thrombolytic therapy. *Chest* 126 (3 Suppl): 338S-400S, 2004.
3. Panchagnula N and Brasher WP: Hyperglycemia and venous thromboembolism. *Diagnostics (Basel)* 14: 1994, 2024.
4. Desouza C and Antao N: Potpourri-recent and relevant literature in periprosthetic fractures around the knee. *J Clin Orthopaedics* 9: 52-56, 2024.
5. Alcaide D, Litten R, Krout JC, Hawkins G, Smitherman A, McIlwain R, McGwin G, Spitler C and Johnson J: Factors influencing patient-reported outcomes in operatively managed tibial plateau fractures. *Eur J Orthop Surg Traumatol* 36: 117, 2026.
6. Nam D, Nunley RM, Johnson SR, Keeney JA, Clohisey JC and Barrack RL: The effectiveness of a risk stratification protocol for thromboembolism prophylaxis after hip and knee arthroplasty. *J Arthroplasty* 31: 1299-1306, 2015.
7. Lurie JM, Png CYM, Subramaniam S, Chen S, Chapman E, Aboubakr A, Marin M, Faries P and Ting W: Virchow's triad in 'silent' deep vein thrombosis. *J Vasc Surg Venous Lymphat Disord* 7: 640-645, 2019.
8. Almskog LM and Ågren A: Thromboinflammation vs. immunothrombosis: Strategies for overcoming anticoagulant resistance in COVID-19 and other hyperinflammatory diseases. Is ROTEM helpful or not? *Front Immunol* 16: 1599639, 2025.
9. Jiang J, Guan ZP and Lü HS: Correlation between single nucleotide polymorphism of prothrombin gene G20210 and deep vein thrombosis after total joint replacement. *Zhonghua Yi Xue Za Zhi* 89: 782-785, 2009 (In Chinese).
10. Reed CR, Curry N, Juffermans NP and Neal MD: Hemostatic abnormalities after trauma resuscitation: Challenges and strategies in caring for the critically injured patient. *Ann Intensive Care* 15: 163, 2025.
11. Jovanović S, Elek Z, Petrović D, Igrutinović G, Vićentijević D and Božović A: Significance of increased D-dimer values in fresh fractures in orthopedics and correlations with thromboembolic complications. *Int J Med Sci Res* 1: 17-22, 2022.
12. May JE, Allen AL, Samuelson Bannow BT, O'Connor C, Sylvester KW and Kaatz S: Safe and effective anticoagulation use: Case studies in anticoagulation stewardship. *J Thromb Haemost* 23: 779-789, 2025.
13. Peng X, Wan J, Wang Y and Wang L: Development of a clinical prediction model for pathological upgrading in low-grade squamous intraepithelial lesions following cervical conization. *Cytojournal* 21: 37, 2024.
14. He W, Liu W, Liu X and Tan W: The mechanism of L1 cell adhesion molecule interacting with protein tyrosine kinase 2 to regulate the focal adhesion kinase-growth factor receptor-bound protein 2-son of sevenless-rat sarcoma pathway in the identification and treatment of type I high-risk endometrial cancer. *Cytojournal* 21: 34, 2024.
15. Wang B, Peng C, Zhou MK, Guo J and He L: Clinical characteristics and prognosis of patients with cerebral venous sinus thrombosis in southwest China. *Sichuan Da Xue Xue Bao Yi Xue Ban* 45: 515-518, 2014 (In Chinese).
16. Wang C, Hang Y, Cao Y, Zhao L, Jiao J, Li M, Xu X, Lu S, Jiang L, Liu Q, *et al*: A nomogram for predicting thrombus composition in stroke patients with large vessel occlusion: Combination of thrombus density and perviousness with clinical features. *Neuroradiology* 65: 371-380, 2022.
17. Li Z, Liu X, Li L, Cao P, Zhang G, Jiao Z, Wang F, Hao Q, Li Y and Zhang Y: Development and validation of a predictive nomogram for lower extremity deep vein thrombosis dislodgement in orthopedic patients. *Front Surg* 10: 1148024, 2023.
18. Liu L, Zhao B, Xu G and Zhou J: A nomogram for individualized prediction of lower extremity deep venous thrombosis in stroke patients: A retrospective study. *Medicine (Baltimore)* 101: e31585, 2022.

19. Greenwald LJ, Yost MT, Sponseller PD, Abdullah F, Ziegfeld SM and Ain MC: The role of clinically significant venous thromboembolism and thromboprophylaxis in pediatric patients with pelvic or femoral fractures. *J Pediatr Orthop* 32: 357-3561, 2012.
20. Saklad M: Grading of patients for surgical procedures. *Anesthesiology* 2: 281-284, 1941.
21. Mahoney FI and Barthel DW: Functional evaluation: The Barthel index. *Md State Med J* 14: 61-65, 1965.
22. Braden B and Bergstrom N: The braden scale for predicting pressure sore risk. *Nurs Res* 36: 205-210, 1987.
23. Yen D and Weiss W: Results of adjusted-dose heparin for thromboembolism prophylaxis in knee replacement compared to those found for its use in hip fracture surgery and elective hip replacement. *Iowa Orthop J* 27: 47-51, 2007.
24. Zhang Y, Wang H, Li X, Pang P, Luo Z, Cai W, Li W and Hao J: Incidence and risk factors of admission deep vein thrombosis in patients with traumatic fracture: A Multicenter retrospective study. *Front Surg* 9: 961441, 2022.
25. Abelseth G, Buckley RE, Pineo GF, Hull R and Rose MS: Incidence of deep-vein thrombosis in patients with fractures of the lower extremity distal to the hip. *J Orthop Trauma* 10: 230-235, 1996.
26. Diamond SL: When flow goes slow, von willebrand factor can bind red blood cells. *Arterioscler Thromb Vasc Biol* 37: 1595, 2017.
27. Kechaou I, Ben Hassine L, Cherif E, Hassayoun M, Azzabi S, Boukhris I, Kaouech Z, Koöli C and Khalfallah N: Characteristics of deep vein thrombosis in the elderly. *Tunis Med* 93: 38-42, 2015 (In Spanish).
28. Kitachev KV, Khubulava GG, Sazonov AB, Kozlov KL, Kulaga VA, Iurchenko DL, Luk'ianov NG and Iakovlev NN: Pathogenesis of chronic ischemia of the lower extremities in patients of advanced ages. *Adv Gerontol* 21: 97-99, 2008 (In Russian).
29. Kurklinsky AK, Kalsi H, Wysokinski WE, Mauck KF, Bhagra A, Havyer RD, Thompson CA, Hayes SN and McBane RD II: Fibrin d-dimer concentration deep vein thrombosis symptom duration, and venous thrombus volume. *Angiology* 62: 253-256, 2010.
30. Dunjić R, Elezović I and Vukasinović Z: Haemostatic disorders in orthopaedic surgery: Laboratory diagnosis. *Srp Ark Celok Lek* 137: 567-574, 2009 (In Serbian).
31. Alexandru N, Popov D and Georgescu A: Platelet dysfunction in vascular pathologies and how can it be treated. *Thromb Res* 129: 116-126, 2011.
32. Hattori A, Watanabe T and Izumi T: Scanning electron microscope study on hemostatic reaction. Mural thrombus after the removal of endothelium, with special references to platelet behavior, site of fibrin formation and microhemolysis. *Arch Histol Jpn* 41: 205-227, 1978.
33. Muthard R and Diamond S: Blood clots are rapidly assembled hemodynamic sensors: Flow arrest triggers intraluminal thrombus contraction. *Blood* 120: 2164, 2012.
34. Wang J, Zan Q and Xie S: Discussion on Prevention and Treatment of Lower Extremity Deep Venous Thrombosis in Orthopedic Perioperative Period from Spleen and Stomach Meridians. *J Clin Nurs Res* 5, 2021 doi:10.26689/jcnr.v5i1.1777.
35. Bah MB, Baldé EY, Camara OM, Keita FB, Barry IS, Diallo H, Kossa AJ, Koné A and Baldé MD: Deep vein thrombosis of the lower limbs: Epidemiology and risk factors. *Cardiol Vasc Res* 9: 1-5, 2025.
36. Alderden J, Cummins MR, Pepper GA, Whitney JD, Zhang Y, Butcher R and Thomas D: Midrange Braden subscale scores are associated with increased risk for pressure injury development among critical care patients. *J Wound Ostomy Continence Nurs* 44: 420-428, 2017.
37. Ramanathan R, Gu Z, Limkemann AJ, Chandrasekhar S, Rensing E, Mays C and Duane TM: Association between interruptions in chemical prophylaxis and VTE formation. *Am Surg* 81: 732-737, 2020.
38. Luo Z, Chen W, Li Y, Wang X, Zhang W, Zhu Y and Zhang F: Incidence of deep venous thrombosis (DVT) of the lower extremity in patients undergoing surgeries for ankle fractures. *J Orthop Surg Res* 15: 294, 2020.
39. Tan Z, Hu H, Wang Z, Wang Y and Zhang Y: Prevalence and risk factors of preoperative deep venous thrombosis in closed patella fracture: A prospective cohort study. *J Orthop Surg Res* 16: 404, 2021.
40. Wang Z, Lu Y, Wang P, Fei C, Li S, Xue H, Li Z, Wang Q, Zhang K and Ma T: Suboptimal use of DOACs Post-discharge for geriatric hip fractures with isolated calf deep vein thrombosis: Do clinician prescribing preferences and patient compliance alters clinical outcomes? *Clin Interv Aging* 18: 1423-1436, 2023.
41. Yao W, Tang WY, Wang W, Lv QM and Ding WB: Development and validation of preoperative proximal and distal limb deep vein thrombosis nomograms in geriatric hip fracture patients. *Eur Rev Med Pharmacol Sci* 27: 10269-10283, 2023.
42. Xu Y, Zhang Z, Si D, Zhang Q and Zhang W: A new nomogram prediction model for left ventricular thrombus in patients with left ventricular aneurysm after acute myocardial infarction. *Rev Cardiovasc Med* 25: 377, 2024.
43. Zheng F, Chen X, Huang J and Lin C: Study on risk factors of preoperative deep vein thrombosis in patients with lower limb fractures and construction and validation of risk prediction nomogram model. *BMC Surg* 24: 408, 2024.
44. Han S, Bai Y, Jiao K, Qiu Y, Ding J, Zhang J, Hu J, Song H, Wang J, Li S, *et al*: Development and validation of a newly developed nomogram for predicting the risk of deep vein thrombosis after surgery for lower limb fractures in elderly patients. *Front Surg* 10: 1095505, 2023.
45. Lin Z: Nomogram for predicting deep venous thrombosis in lower extremity fractures. *Front Surg* 8: 694042, 2021.
46. Ling H, Li W, Deng G, Lao Y, Lu R, Su W and Huang Z: Development of a nomogram for deep vein thrombosis in patients with Tibial plateau fractures based on systemic Immune-inflammation index. *Sci Rep* 14: 23888, 2024.
47. Wu L and Cheng B: A nomogram to predict postoperative deep vein thrombosis in patients with femoral fracture: A retrospective study. *J Orthop Surg Res* 18: 463, 2023.
48. Yang S, Zhang E, Li Z, Long Y, Li Y, Zhang J, Wang F, Liu L, Wang T, Guo J and Hou Z: Deep vein thrombosis in patients with patellar fractures: Assessing incidence rates and identifying risk factors. *PLoS One* 20: e0316628, 2025.
49. Lin Z, Mi B, Liu X, Panayi AC, Xiong Y, Xue H, Zhou W, Cao F, Liu J, Hu L, *et al*: Nomogram for predicting deep venous thrombosis in lower extremity fractures. *Biomed Res Int* 2021: 9930524, 2021.
50. Shi H, Zhou Y, Wang Y *et al*: Nomogram to predict preoperative deep vein thrombosis risk in patients with isolated calcaneal fracture. *J Orthop Surg Res* 17: 467, 2022.
51. He L, Luo L, Hou X, Liao D, Liu R, Ouyang C and Wang G: Predicting venous thromboembolism in hospitalized Trauma patients: A combination of the caprini score and data-driven machine learning model. *BMC Emerg Med* 21: 60, 2021.



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