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A nomogram model for predicting preoperative DVT in elderly anemic patients undergoing total hip arthroplasty: a retrospective cohort study

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Abstract

Objectives Total hip arthroplasty (THA) is classified as a high-risk surgery for venous thromboembolism (VTE) events, especially in elderly individuals and in cases of anemia. This study aims to uncover independent risk factors for predicting preoperative DVT in elderly anemic patients undergoing THA. Furthermore, it seeks to validate these factors' predictive efficacy in diagnosing DVT, with the goal of facilitating prompt identification and treatment to mitigate associated risks.

Methods Clinical information and relevant laboratory test data of preoperative deep vein thrombosis (DVT) in 459 elderly patients with anemia who underwent total hip replacement surgery from January 2018 to June 2024 were retrospectively evaluated. Logistic regression analysis and backward stepwise method were used to detect independent predictors of preoperative DVT diagnosis in elderly patients with anemia who underwent total hip replacement surgery. A nomogram prediction model was established through multivariate logistic regression and subsequently utilized the testing group to validate.

Results A multivariate logistic regression model was used to analyze the data, Hematocrit (HCT) (Odds ratio (OR) = 0.14, 95% confidence intervals (CI):[0.04,0.52]; $P = 0.003$), Albumin (ALB) (OR = 0.1, 95% CI:[0.03,0.37]; $P = 0.001$), Prothrombin Time (PT) (OR = 0.29, 95% CI:[0.1,0.83]; $P = 0.02$), Fibrin Degradation Products (FDP) (OR = 0.15, 95% CI:[0.05,0.49]; $P = 0.002$) and lymphocyte/Monocyte ratio (LMR) (OR = 0.28, 95% CI:[0.09,0.87], $P = 0.028$) were independent predictors for DVT before THA in elderly patients with anemia. The area under the curve (AUC) scores were 0.929 for the training group and 0.896 for the testing group, with calibration curve mean errors of 0.017 and 0.023, respectively. The decision curve analysis (DCA) graph indicates that the developed nomogram was highly practical and advantageous for clinical application.

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Conclusion The independent predictors of preoperative DVT in elderly anemic patients undergoing total hip replacement primarily include HCT, ALB, PT, FDP, and LMR at admission, which are easy to obtain and can quickly yield results. Moreover, the nomogram based on HCT, ALB, PT, FDP, and LMR can help clinical doctors evaluate the possibility of DVT formation, thereby accurately and quickly assisting clinical doctors in making better clinical judgments.

Keywords Deep Venous Thrombosis (DVT), Total hip arthroplasty (THA), Anemia, Nomogram, HCT, ALB, PT, FDP, LMR

Introduction

Total hip replacement is a mature orthopedic surgical technique, but the surgery may bring some inevitable risks and complications [1, 2]. There are many factors that lead to poor prognosis and death in individuals, one of which is deep vein thrombosis (DVT). Even if there are many medical or physical prevention measures for thrombosis, it still brings high incidence rate, high mortality and high medical costs to patients [3]. Moreover, recent research indicates that patients with anemia who undergo joint replacement surgery are at a heightened risk for developing preoperative DVT, and the severity of anemia has been directly correlated with an increased likelihood of DVT occurrence [4, 5]. Unfortunately, due to the complexity and diversity of clinical situations, as well as the lack of clear clinical symptoms and signs, DVT cannot be accurately predicted. Delay in diagnosis and treatment can lead to embolism of the thrombus, which can lead to pulmonary embolism, a life-threatening condition [6].

In clinical practice, there are many ways to diagnose DVT, one of the most important is ultrasonic Doppler examination, which is simple and non-invasive [7]. However, many factors such as poor posture, acute limb edema, local skin defect or rupture may reduce the accuracy of the results. In addition to ultrasound, the Caprini score and Geneva score, which are commonly used in clinical practice, can also be used to reflect the risk of venous thrombosis. The Caprini scoring system has the advantages of comprehensiveness, predictability, wide applicability, and evidence-based support. In individuals who have undergone THA, the score is generally high, indicating a substantial risk for VTE formation [8]. However, the Caprini scoring system indicators have limitations such as complexity, subjectivity, and individual differences [9]. Geneva scoring system is mainly used to assess the risk of pulmonary embolism and may not be applicable to other types of VTE risk assessment, such as deep vein thrombosis (DVT) [10]. In addition, many laboratory indicators of VTE patients may undergo changes, including activated partial thromboplastin time (APTT), thrombin time (TT), prothrombin time (PT), d-dimer levels, fibrinogen degradation products (FDP), and platelet count (PLT). The advantage of coagulation function testing lies in its comprehensiveness, non-invasiveness, and rapidity, making it suitable for various clinical situations. However, its non-specific nature, sensitivity limitations, and complexity in interpreting results also require clinical doctors to make comprehensive judgments when using it, and if necessary, combine other examination methods to ensure accurate diagnosis and treatment [11, 12].

Recently, in addition to the three main factors in the pathophysiology of thrombosis, the immune inflammatory system has gradually been discovered as another mechanism affecting thrombus formation. Patients undergoing total hip replacement surgery typically suffer from acute or chronic inflammatory diseases. Inflammatory processes trigger white blood cells to release various pro-inflammatory and pro-oxidative cytokines, which not only promote clotting but also inhibit fibrinolysis, the process of breaking down clots. Moreover, elevated levels of these cytokines can contribute to vascular endothelial damage, exacerbating the thrombosis risk [13]. Recent advancements have introduced several peripheral blood indicators that serve as systemic inflammatory markers across various medical conditions such as malignant tumors, cardiovascular diseases, fractures, and severe traumas [14–18]. These indicators include neutrophil/lymphocyte ratio (NLR), the platelet/lymphocyte ratio (PLR), lymphocyte/monocyte ratio (LMR), platelet/white blood cell ratio (PWR), platelet/neutrophil ratio (PNR), systemic immune-inflammation index ((platelet × neutrophil)/lymphocyte, SII), and pan immune-inflammation value (PIV). The markers mentioned above can be found through routine blood tests at no extra cost and can be predictive [19]. The adoption of these novel inflammatory indicators has gradually expanded into the realm of orthopedic surgery and its associated complications [20, 21]. Their utility lies in providing clinicians with valuable information regarding the patient's inflammatory status, aiding in risk assessment, treatment planning and postoperative management strategies in total hip replacement and other orthopedic procedures.

The nomogram is a recently developed predictive model that is characterized by ease of use, user-friendliness, and practicality, which collectively make it a valuable tool for clinical physicians [22]. An increasing number of scholars are focusing on the development and validation of nomograms, reflecting a growing clinical

consensus on the importance of early preventive interventions for DVT. This underscores the critical need for establishing a robust nomogram for DVT [23, 24]. Therefore, exploring and synthesizing the correlation between thrombosis related indicators and novel inflammatory indicators with preoperative thrombosis in elderly anemic patients undergoing THA, and establishing a nomogram to evaluate the risk of DVT events based on this, can help more accurately identify and manage the risk of thrombosis in patients.

Methods

Study samples

This retrospective study selected all patients who underwent total hip replacement surgery at Huizhou Central People's Hospital from January 2018 to June 2024(a total of 2225 patients). Those patients who met the criteria below were included(a total of 806 patients): (1) Blood routine examination within 24 h of admission diagnosed anemia. According to the 2011 World Health Organization standards (as well as the index referenced from the laboratory of Huizhou Central People's Hospital), hemoglobin (Hb) < 130 g/L in males and < 115 g/L in females are defined as anemia; (2) Patients diagnosed with unilateral/bilateral hip osteoarthritis, avascular necrosis of the femoral head, femoral neck fracture, and receiving initial total joint replacement surgery upon admission. The following cases were excluded from the study: (1) Patients lacking sufficient clinical data, including incomplete or absent medical histories and preoperative Doppler ultrasonography reports (78 patients); (2) Patients under 60 years of age (148 patients); (3) Patients diagnosed at admission with multiple fractures, pathological fractures, fractures or joint infections, poor prognosis of traumatic fractures, prior or recent use of anticoagulants, inflammatory or infectious illnesses, use of anti-infective drugs, ambiguous infection diagnosis at admission, hematologic diseases, bone tumors, or other types of tumors (121 patients). Ultimately, 459 patients were included in our study.

Variable extraction and data pre-processing

We gathered comprehensive clinical data for each case, encompassing age, gender, primary diagnosis, height, weight, systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse rate (measured at admission), breathe per minute (BPM, measured at admission), body temperature (measured at admission), history of smoking, alcoholism, hypertension and diabetes. We classified patients as hypertensive if they had a medical history of hypertension or if their SBP/DBP levels recorded at admission exceeded 140/90 mmHg. Diabetes was diagnosed in individuals with a prior history of the condition or those who, after hospitalization, had fasting blood glucose (FBG) levels exceeding 7 mmol/L and random blood glucose levels exceeding 11.1 mmol/L. Additionally, we documented the laboratory testing results obtained by patients in the emergency room or within the first 24 h of admission, including blood routine tests, coagulation function tests, and biochemical tests. During a complete blood count performed immediately upon admission to the emergency department or hospital, data on WBC, PLT, NC, LYM, and MNC are collected to assess relevant inflammation and immune indices. The formulas used are as follows:

$$\mathrm{NLR} = \mathrm{NC/LYM};\ \mathrm{LMR} = \mathrm{LYM/MNC};\ \mathrm{PLR} = \mathrm{PLT/LYM};\ \mathrm{PWR} = \mathrm{PLT/WBC};$$
$$\mathrm{PNR} = \mathrm{PLT/NC};\ \mathrm{SII} = \mathrm{PLT} \times \mathrm{NC/LYM};\ \mathrm{PIV} = \mathrm{NC} \times \mathrm{MNC} \times \mathrm{PLT/LYM}.$$

Study outcome

The DVT event occurring before total hip replacement surgery in elderly anemic patients is regarded as an outcome event for this study. Results are categorized as DVT if the outcome event is positive, and as no DVT if negative. The label "Thrombosis" is used to denote the occurrence of DVT based on preoperative color Doppler ultrasound findings. The criteria for diagnosing DVT were determined from the results of color Doppler ultrasonography, as detailed below: 1.Main criteria: (1) The lumen cannot be compressed; (2) Solid echo within the lumen; (3) Deficiency of blood flow signal filling in the official cavity; (4) Loss of phase change in blood flow spectrum; (5) Vanke's reaction disappears or weakens; (6) Squeeze the distal limb to enhance or weaken blood flow. 2.Secondary criteria: (1) The increase in venous diameter during Valsalva maneuver is less than 10%; (2) Widening or shrinking of venous inner diameter; (3) Valve changes (thickening, stiff movement, or fixation); (4) Formation of collateral circulation around veins. The above diagnostic DVTs were evaluated by a senior ultrasound imaging doctor using color Doppler ultrasound and providing a diagnostic report to identify DVT, including testing of bilateral common femoral veins, superior/deep femoral veins, popliteal veins, anterior and posterior tibial veins, and fibular veins. Superficial vein thrombosis is excluded from this study due to the limited clinical relevance of superficial and intramuscular veins.

Statistical analysis

Prior to conducting the data analysis, we randomly assigned patients using R Studio version 4.3.1 (The R Foundation for Statistical Computing, Vienna, Austria) into a training group ($n=321$) and a testing group ($n=138$) at a ratio of 7:3. SPSS 26 (SPSS Inc., Chicago, IL, USA) was used to assess the normality of the data. Normally distributed continuous variables were described using mean and standard deviation and compared using t-tests, while non-normally distributed variables were described using median and quartiles and compared using rank sum tests. Categorical variables were presented as percentages (n %) and compared using chi-square tests or Fisher's exact test when appropriate. In order to ensure comparability between the two groups and the effectiveness of the prediction model, a comparison was conducted of the baseline data for both groups (Supplementary Information: Table 1).

Within the training group, patients were further categorized into subgroups based on the occurrence of DVT: DVT subgroup ($n=36$) and No DVT subgroup ($n=285$). Data between these subgroups were compared using rank sum tests, t-tests, Fisher's exact tests and chi-square tests as appropriate. Violin plots were generated using R Studio (version 4.3.1) to visualize differences in age, PLT, HB, HCT, LYM, NC, ALB, HDL-C, APTT, PT, FDP, NLR, LMR, SII, PIV, PWR and PNR. ROC curves were constructed to assess the predictive power of these variables for DVT. Each variable was classified into high and low groups based on the aforementioned cutoff values. Univariate logistic regression was initially performed to identify variables associated with the outcome event, with odds ratios (ORs) and 95% confidence intervals (CIs) calculated. Incorporating variables with $P<0.05$ from the univariate analysis, a backward stepwise approach was used to identify independent predictors of DVT in the multivariate regression analysis. Statistical significance was set at $P<0.05$ for two-sided tests. The creation of a nomogram predictive model was enabled by the utilisation of significant variates from the aforementioned multivariate regression analysis, visualisation of which was facilitated through the use of R Studio (version 4.3.1). The model's predictive accuracy was assessed through ROC curves and the area under the curve (AUC), while its goodness of fit was evaluated using calibration curves and mean absolute error. Decision curve analysis (DCA) was performed to evaluate the clinical utility of the nomogram using different high-risk thresholds.

The criteria for grouping and the construction process for the model are illustrated in Fig. 1.

Results

Baseline characteristics

The 459 cases included in the study were randomly allocated to either the training or testing group in a 7:3 ratio. The training group was composed of 124 men (38.63%) and 197 women (61.37%), with an average age of 74 years (67,83) and an average BMI of 22.15 kg/m^2(20.25,23.78). The testing group consisted of 53 men (38.41%) and 85 women (61.59%), with a mean BMI of 22.15 (20.35,23.44) kg/m^2 and a mean age of 74.5 (66,84) years, respectively. There were a number of factors that were not statistically significant between the groups studied ($P>0.05$): thrombosis, sex, age, smoke, alcoholism, hypertension, diabetes, BMI, SBP, DBP, pulse, BPM, and body temperature. These findings support the training and validation of the model in both groups (Supplementary Information: Table 1).

The training group was subdivided into two subgroups on the basis of the findings of preoperative vascular color Doppler ultrasonography. The first subgroup, designated as the "No DVT" subgroup, consisted of 285 individuals, while the second subgroup, termed the "DVT" subgroup, included 36 individuals. The No DVT subgroup consisted of 114 men (40%) and 171 women (60%), with an average age of 74 (67,82)years and a BMI of 22.15 (20.4,23.81) kg/m^2. In contrast, the DVT subgroup included 10 men (27.78%) and 26 women (72.22%), with a mean age of 82.5 (70,86.25)years and a BMI of 21.82 (19.88,23.61)kg/m^2. A significant difference was observed in age between the various subgroups ($P<0.05$). However, no significant variations were evident with respect to the baseline characteristics of the subjects, which included sex, smoking, alcoholism, hypertension, diabetes, BMI, SBP, DBP, pulse, BPM, and temperature ($P>0.05$). Upon admission, a series of tests was conducted in order to obtain the necessary data for the purposes of the research project. The tests included blood tests for routine parameters (RBC, WBC, PLT, HB, HCT, LYM, NC and MNC), as well as for biochemical and coagulation factors (ALB, HDL-C, APTT, PT, TT, PT-INR and FDP). Significant differences were found in PLT, HB, HCT, LYM, NC, ALB, HDL-C, APTT, PT and FDP levels between the DVT and No DVT subgroups ($P<0.05$), while RBC, WBC, MNC, TT and PT-INR levels exhibited no discernible differences ($P>0.05$). Correlation analyses were conducted on a range of inflammatory-immune indices, including NLR, PLR, LMR, SII, PIV, PWR and PNR, were derived from routine blood test indexes. Specifically, NLR and PWR showed notable differences between the DVT and No DVT subgroups ($P=0.001$). Similarly, LMR demonstrated statistically significant discrepancies between these two subgroups ($P=0.007$). Significant differences were observed between SII and PIV in the DVT subgroup compared to the No DVT subgroup ($P<0.05$).

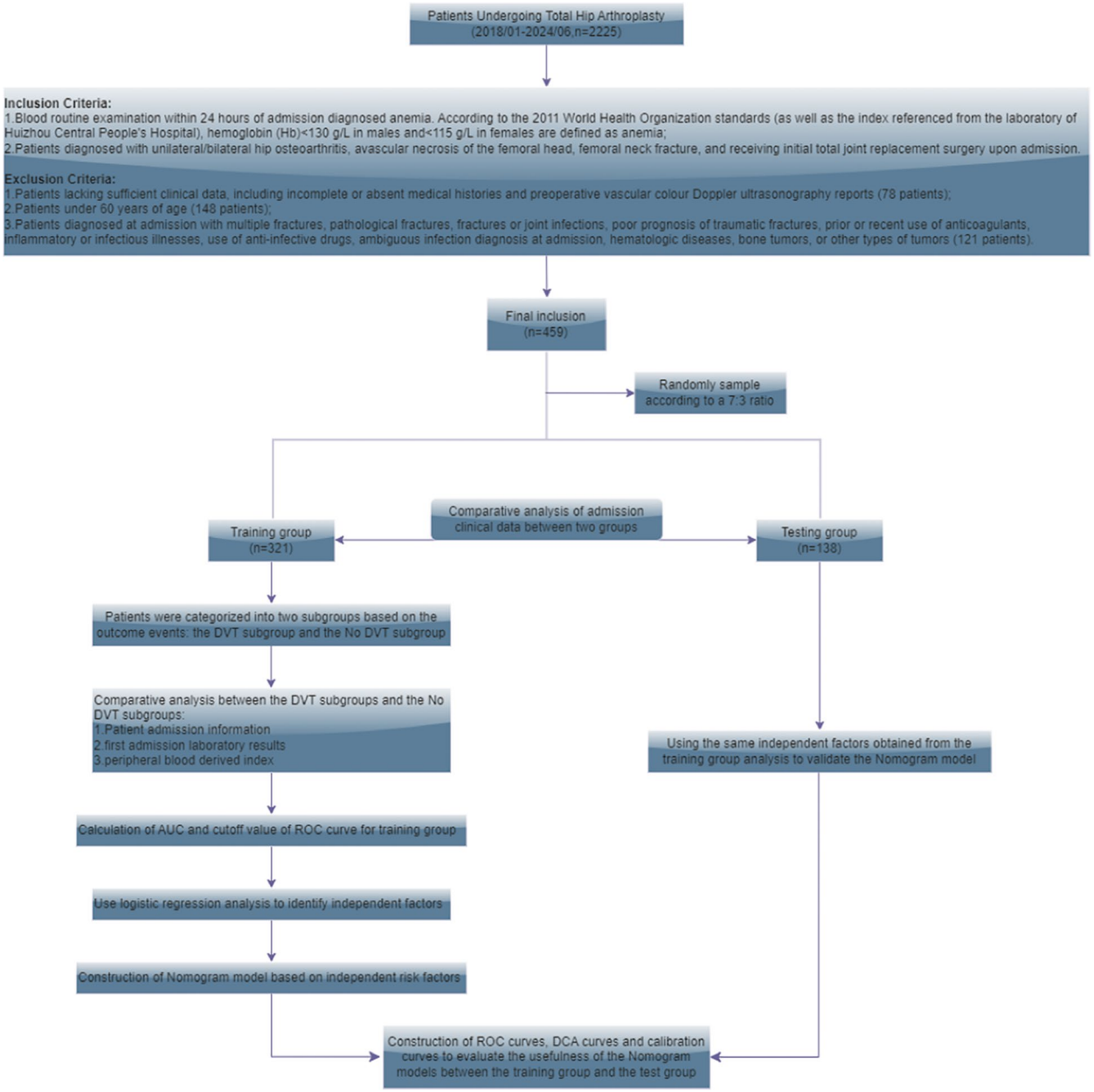

Fig. 1 Flow chart of this study

Additionally, PNR levels were markedly elevated in the DVT subgroup relative to the No DVT subgroup ($P < 0.001$)(Supplementary Information: Table 2).

Analysis of related factors of preoperative DVT in elderly anemic patients undergoing THA

The values of age, NC, HDL-C, NLR, SII, and PIV in the DVT subgroup were notably higher compared to the No DVT subgroup. Conversely, PLT, HB, HCT, LYM, ALB, APTT, PT, FDP, LMR, PWR, and PNR in the DVT subgroup were significantly lower than those in the No DVT subgroup ($P < 0.05$, Supplementary Information: Table 2). The ROC curves revealed the optimal cutoff values for various potentially indicators (Supplementary Information: Table 3), with corresponding sensitivity, specificity, and AUC values, which suggest their potential value as diagnostic indicators for DVT.

The 321 patients were dichotomized into high and low groups based on the ROC cutoff value, facilitating a more nuanced understanding of the relationship

between the previously mentioned differential variables and DVT. As illustrated by the univariate analyses, low PLT, HB, HCT, LYM, ALB, HDL-C, APTT, PT, FDP, LMR, PWR, PNR, and high Age, NC, NLR, SII and PIV were associated with the occurrence of DVT. Through multivariate regression, we finally found that low HCT, low ALB, shortened PT, low FDP, and low LMR constitute independent predictors of preoperative DVT in elderly anemic patients undergoing total hip arthroplasty (Supplementary Information: Table 4).

Predictive nomogram development

Subsequently, to predict the evolution of preoperative DVT in elderly anemic patients undergoing THA, we constructed a nomogram model using HCT, ALB, PT, FDP and LMR based on a binary logistic regression equation (Fig. 2). HCT, ALB, PT, FDP and LMR were treated as binary variables. The nomogram provided a score for each component, with the total score indicating the underlying probability of developing DVT. For the training group, the AUC was 0.929 (Fig. 3A), while for the testing group, it was 0.896 (Fig. 3B). To evaluate the precision of the nomogram, calibration curves were constructed: the training group showed a mean model error of 0.017 (Fig. 4A), and the testing group exhibited 0.023 (Fig. 4B), indicating good conformity between predictions and actual outcomes. The DCA curves for the training group indicated that the model exhibited superior clinical benefits at high-risk thresholds between 0.01 and 0.95 (Fig. 5A). In the testing group,

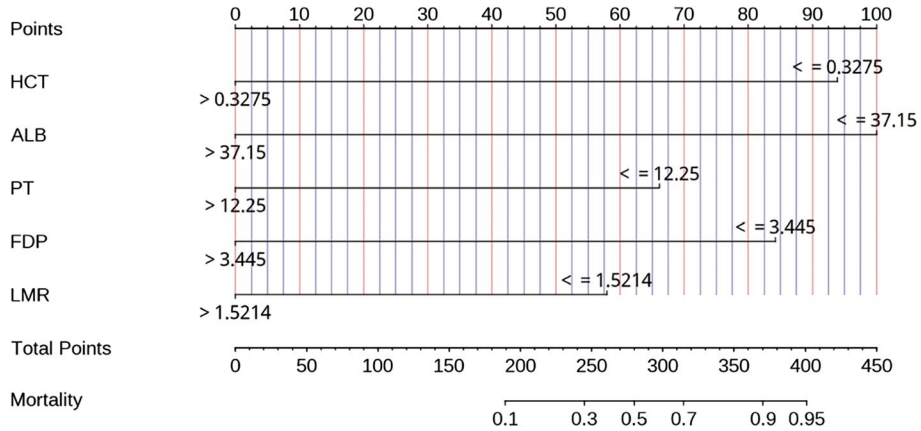

Fig. 2 The Nomogram model of this study obtained through binary logistic regression analysis

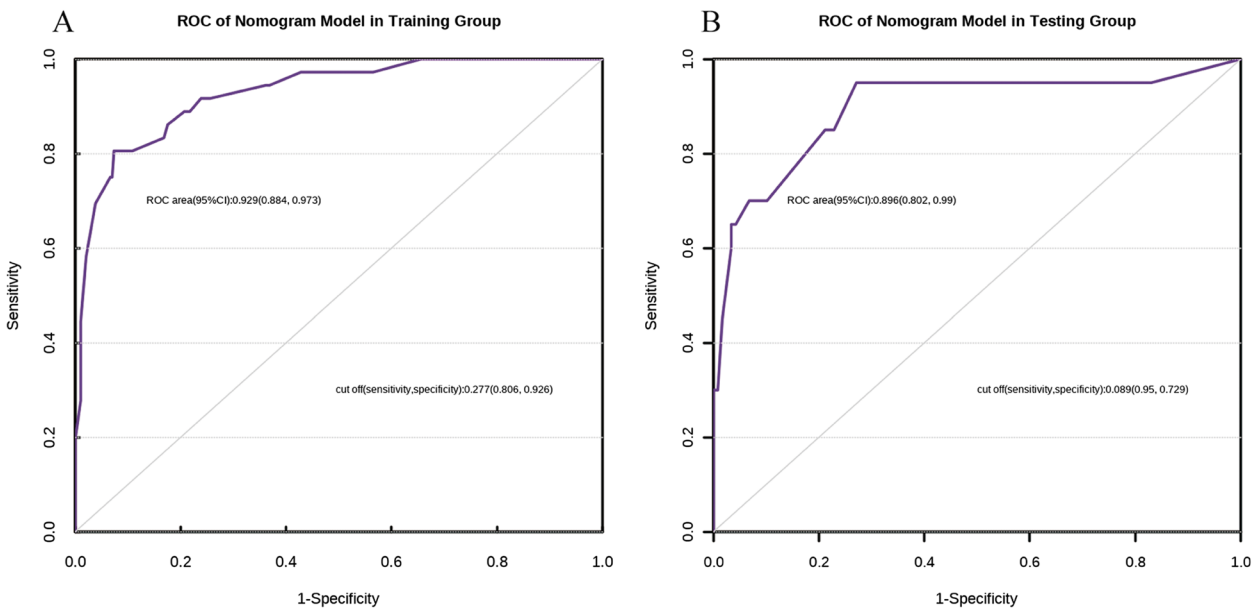

Fig. 3 **A** ROC of Nomogram Model in Training Group; **B** ROC of Nomogram Model in Testing Group

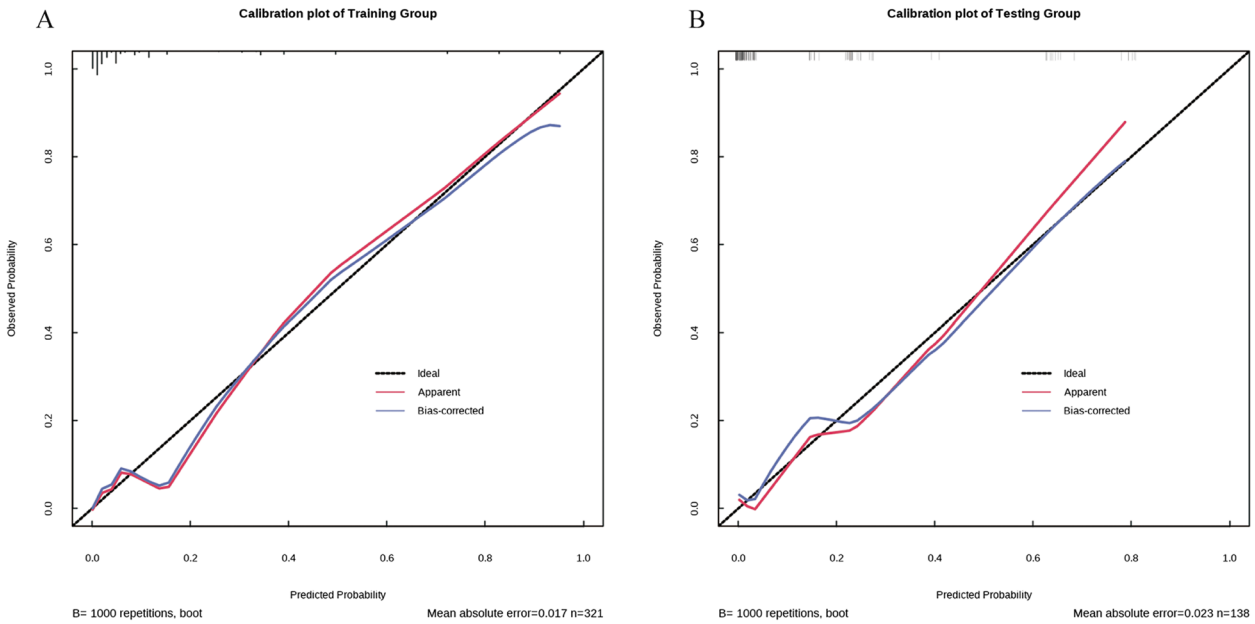

Fig. 4 **A** Calibration plot of Training Group; **B** Calibration plot of Testing Group

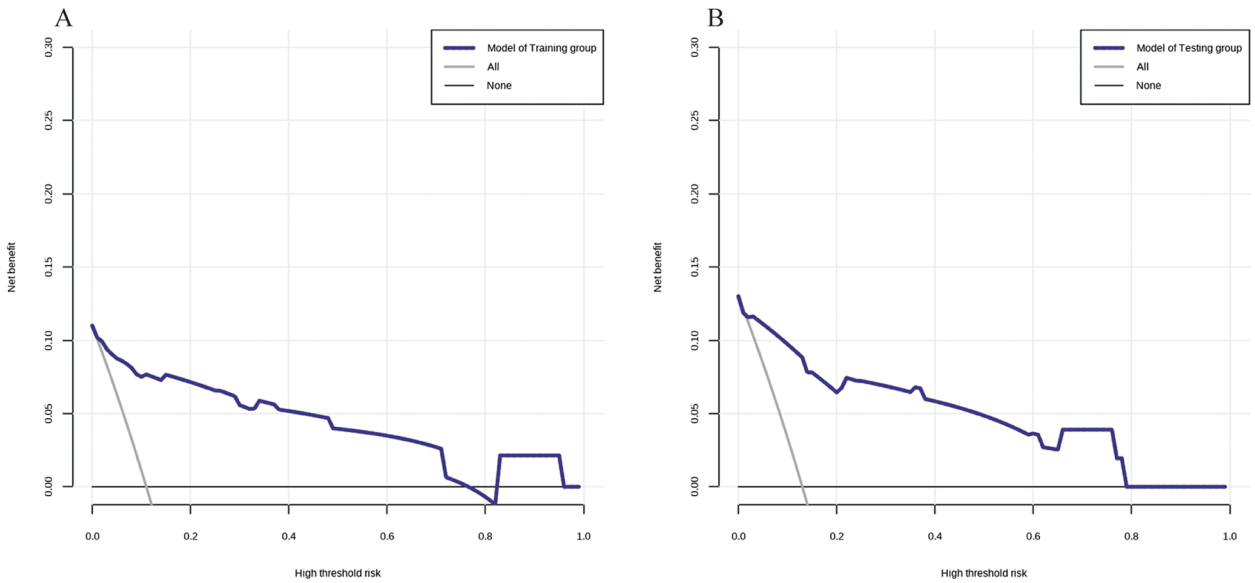

Fig. 5 **A** DCA of Training Group; **B** DCA of testing group

the DCA curve demonstrated higher clinical benefits in the range of 0.02 to 0.74 (Fig. 5B).

Discussion

Total hip arthroplasty (THA) has been demonstrated as an efficacious treatment modality in the management of conditions affecting the hip joint. The rise in global life expectancy and the proportion of the population aged 65 and over, the number of patients undergoing hip replacement surgery is expected to rise significantly in the next decade [25]. In recent years, survival and surgical outcomes analysis has become a research hotspot. Among these, the incidence of complications before and after surgery represents a significant contributor to the elevated rates of disability and mortality observed in these patients. Deep vein thrombosis (DVT) is a significant and

common complication associated with total hip arthroplasty (THA), carrying a high risk of venous thromboembolism (VTE). DVT occurs in approximately 40–60% of patients undergoing hip surgery, with the prevalence of pre-THA DVT reaching up to 29.4% [26]. Research has indicated that patients with anemia or reduced red blood cell counts exhibit an increased risk of VTE compared to individuals with normal hematological parameters. Nevertheless, the limited sensitivity of individual clinical indicators and the delayed results of color Doppler ultrasound examinations in clinical practice frequently impede the timely identification of DVT, leading to a range of adverse consequences, including surgical postponements and, in some instances, fatalities. In this study, multivariate logistic regression analysis identified HCT, ALB, PT, FDP and LMR as independent predictors for diagnosing preoperative DVT in elderly anemic patients undergoing THA. These predictive indicators are readily accessible and straightforward to calculate, thereby enhancing the efficiency of DVT diagnosis and treatment for clinicians. This, in turn, contributes to reducing disability and mortality rates, improving patient outcomes, and ultimately elevating the quality of life for affected individuals. The effectiveness and clinical utility of the nomogram prediction model, constructed using these five factors, were evaluated to facilitate the rapid, precise, and efficient prediction of preoperative DVT in elderly anemic patients undergoing THA.

The influence of preoperative anemia on the development of deep venous thrombosis (DVT) in patients has garnered significant attention within the academic community. Xiong et al. [4] identified a reduced preoperative red blood cell count as a significant risk factor for the development of preoperative DVT in patients undergoing total knee arthroplasty. Moreover, Feng et al. [27] established that preoperative anemia serves as an independent risk factor for VTE among elderly Chinese patients with hip fractures. Their analysis yielded an odds ratio of 0.144 (95% CI: 0.026–0.799, $P=0.027$), underscoring the significant role of preoperative anemia in VTE risk assessment for this patient population. Xiong et al. [5] further established that greater severity of preoperative anemia is associated with an elevated risk of preoperative DVT in patients undergoing total joint arthroplasty (TJA). Consequently, it is recommended to screen for DVT in preoperative anemic patients undergoing TJA. Our research further supports this, revealing that when the threshold for hematocrit (HCT) was set at 0.327, the area under the ROC curve (AUC) was 0.699 (95% CI: 0.621–0.777; $P<0.001$). Additionally, preoperative HCT values below 0.327 were associated with an increased risk of thrombosis (OR = 0.14, 95% CI: [0.04,0.52], $P=0.003$). Thus, HCT emerges as a critical predictive indicator for preoperative DVT in elderly anemic patients undergoing hip replacement surgery. Furthermore, researchers investigated how variations in serum albumin (ALB) concentrations may influence the risk of deep venous thrombosis. Albumin, a major plasma protein, plays essential roles in maintaining plasma colloid osmotic pressure, transporting substances (such as drugs, hormones, and fatty acids), and exerting antioxidant and anti-inflammatory effects. Chen et al. [28] found a significant independent association between low albumin levels and DVT in patients with spontaneous intracerebral hemorrhage. Xiong et al. [29] revealed that patients with lower preoperative albumin levels were more likely to have DVT emerged before undergoing TJA. The thrombosis risk with a preoperative albumin reduction was increased in the current study, similar to those reported in previous studies. Moreover, when preoperative ALB is below 37.15, the risk of thrombosis in patients would be enormously enhanced with increased risk (OR = 0.1, 95% CI: [0.03,0.37], $p=0.001$). Low albumin levels contribute to thrombus formation through various mechanisms, including increased blood viscosity, reduced antioxidant and anti-inflammatory protection, malnutrition, systemic inflammation, and endothelial dysfunction, collectively increasing the risk of thrombosis [30].

Based on our research findings, FDP and PT were identified as independent risk factors for predicting thrombus formation in elderly anemic patients undergoing THA, demonstrating good predictive value. When the FDP threshold was set at 3.445, the AUC was 0.607 (95% CI: 0.499–0.715; $P=0.001$). Similarly, when the PT threshold was set at 12.25, the AUC was 0.619 (95% CI: 0.519–0.717; $P=0.001$). Moreover, multiple logistic regression analysis showed that the risk of thrombosis increased when preoperative PT and FDP were lower than the optimal cutoff values mentioned above (OR = 0.15, 95% CI: [0.05,0.49], $p=0.002$; OR = 0.29, 95% CI:[0.1,0.83], $p=0.02$). Fibrinogen degradation products (FDP) are produced when fibrinogen is degraded during the process of thrombus formation and dissolution. Changes in FDP levels reflect the dynamic balance of thrombus formation and dissolution in the body [31]. Low FDP levels may indicate decreased fibrinogen degradation, potentially leading to increased thrombus stability and reduced dissolution [32]. Prothrombin time (PT) is an important indicator for assessing the extrinsic coagulation pathway, where a shorter PT (faster coagulation time) generally signifies accelerated clotting [33]. However, in clinical assessment of thrombotic risk, a comprehensive evaluation of multiple factors is typically necessary, rather than relying solely on individual indicators such as FDP and PT.

Traditionally, thrombosis was understood primarily through Virchow's triad, encompassing endothelial injury, hypercoagulability, and blood stasis [34]. However, emerging evidence underscores the significant role of the immune-inflammatory system in the pathogenesis of thrombosis. Thrombosis is closely associated with inflammation, as the inflammatory process can activate the coagulation system, thereby promoting clot formation [35]. During inflammation, the body releases pro-inflammatory factors such as cytokines (IL-6, TNF-α), interleukins (IL-1, IL-8), and tumor necrosis factor. These factors can enhance platelet activation and the generation of coagulation factors, thereby increasing the risk of thrombosis. In an inflammatory state, damage to endothelial cells leads to increased reactivity of the vessel wall to platelets and coagulation factors, further facilitating thrombus formation. Additionally, inflammation and thrombosis can establish a vicious cycle, where thrombosis itself can trigger local inflammatory responses, leading to further release of inflammatory mediators and endothelial damage, thereby amplifying the risk of thrombosis [3, 36, 37]. The lymphocyte-to-monocyte ratio (LMR), as a novel inflammatory factor and prognostic indicator, collectively represents the immune-inflammatory system's impact on thrombosis, garnering increasing research attention [21, 38]. In our study, we found that LMR independently predicts preoperative thrombosis in elderly anemic patients undergoing THA, demonstrating good predictive capability (AUC, 0.638; 95% CI: 0.532–0.744; $P < 0.001$). Due to its ease of acquisition and convenient operation, LMR facilitates faster diagnosis and more precise treatment in clinical practice.

Recent years have witnessed an increasing academic trend in using nomograms to predict the risk of developing DVT. The nomogram in this study is constructed based on blood test results obtained at the time of patient admission, incorporating the combined effects of factors such as HCT, ALB, PT, FDP, and LMR. This model facilitates quicker and more accurate diagnosis and the selection of appropriate treatment methods, demonstrating robust predictive capabilities. Nevertheless, this study is accompanied by several limitations that warrant consideration: (1)It is a single-center, retrospective analysis, which may introduce potential biases and limit generalizability due to the restricted sample size and the presence of confounding variables. Important clinical risk factors, such as detailed patient medical histories, were not thoroughly examined. Future research should consider conducting multi-center regression studies and thoroughly examining the data on risk variables to refine the predictive accuracy and overall effectiveness of the model. (2) This study lacked external data validation, leaving the model's accuracy and applicability unconfirmed. Future multi-center retrospective studies should incorporate data from various hospitals to externally validate and confirm the model's reliability. (3)This study excluded a significant number of cases, resulting in a narrow scope for the nomogram. Future multi-center studies should maximize the sample size to the greatest extent feasible while strictly adhering to inclusion and exclusion criteria. (4)This study concentrated solely on the risk of preoperative DVT. Subsequent research should extend to evaluate the risk of postoperative DVT.

Conclusion

The independent predictors of preoperative DVT in elderly anemic patients undergoing total hip replacement primarily include HCT, ALB, PT, FDP, and LMR at admission, which are easy to obtain and can quickly yield results. Moreover, the nomogram based on HCT, ALB, PT, FDP, and LMR can help clinical doctors evaluate the possibility of DVT formation, thereby accurately and quickly assisting clinical doctors in making better clinical judgments.

Abbreviations

DVT	Deep vein thrombosis
VTE	Venous thromboembolism
THA	Total hip arthroplasty
TJA	Total joint arthroplasty
BMI	Body mass index
APTT	Activated partial thromboplastin time
PT	Prothrombin time
TT	Thrombin time
PT-INR	Prothrombin Time - International Normalized Ratio
FDP	Fibrin degradation products
PLT	Platelet count
MNC	Mononuclear cell
NC	Neutrophilic cell
LYM	Lymphocyte
WBC	White Blood cell
RBC	RED Blood cell
HCT	Hematocrit
HB	Hemoglobin
ALB	Albumin
HDL-C	High-density lipoprotein cholesterol
FBG	Fasting blood glucose
DBP	Diastolic blood pressure
SBP	Systolic blood pressure
NLR	Neutrophil/lymphocyte ratio
PLR	Platelet/lymphocyte ratio
LMR	lymphocyte/Monocyte ratio
SII(Systemic immune-inflammation index)	Platelet × Neutrophilic cell/Lymphocyte ratio
PIV(pan immune-inflammatory value)	Neutrophilic × Mononuclear × Platelet/lymphocyte ratio
PWR	Platelet/White Blood cell ratio
PNR	Platelet/Neutrophilic ratio
DCA	Decision curve analysis
AUC	Area under the curve
ROC	Receiver operating characteristic curve
ORs	Odds ratios
CIs	Confidence intervals

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12959-025-00698-9.

Supplementary Material 1. Table 1 Baseline data table of all studied patients.

Supplementary Material 2. Table 2 Comparison of clinical data between the No DVT subgroup and the DVT subgroup in the training group.

Supplementary Material 3. Table 3 AUC and Cutoff value of ROC curve in the significant variables.

Supplementary Material 4. Table 4 Outcomes of the binary logistic regression analysis.

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Not applicable.

Authors' contributions
Yutai Li and Chunhan Sun were responsible for the study design and conception. Yutai Li, Guowei Zeng, and Guihua Liu organized the database. Yutai Li, Weicong Yin, and Shoubin Huang conducted the statistical analyses. Yutai Li was in charge of the drafting of the manuscript. Yutai Li, Guowei Zeng, Weicong Yin, Shaowei Zheng, Luyuan Yang and Huangze Yan contributed to writing various sections of the manuscript. Yutai Li and Huikun Cao were involved in preparing the tables and figures. All authors reviewed and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki and received approval from the Clinical Research Ethics Committee of Huizhou Central People's Hospital (approval number: kyll2024200). Given the retrospective nature of the study, the Ethics Committee waived the requirement for informed consent.

Consent for publication
To safeguard the privacy of study participants, all personally identifiable information was rendered anonymous.

Competing interests
The authors declare no competing interests.

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