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ORIGINAL RESEARCH

Development of a Predictive Nomogram Model for Early Deep Vein Thrombosis in Postoperative Spontaneous Intracerebral Hemorrhage Patients

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Background: This study explores risk determinants for participants' lower extremities deep vein thrombosis (DVT) in the perioperative phase after spontaneous intracerebral hemorrhage (SICH), thereby informing more effective clinical prevention and treatment strategies.

Methods: During the period spanning October 2021 to March 2024, clinical data from 96 participants who received surgical treatment for spontaneous cerebral hemorrhage was analyzed in a retrospective study. Participants were classified into DVT and negative-DVT groups within the first week post-surgery. We used univariate logistic regression and multivariate logistic regression analyses to assess the impact of various clinical variables on DVT. A nomogram model was constructed to forecast the occurrence of early DVT following SICH surgery. The model's performance was assessed and validated using receiver operating characteristic (ROC) curves and bootstrap resampling.

Results: Among the 96 participants, 46 developed DVT. Significant differences were noted in age, D-dimer levels, fibrinogen degradation products, Caprini scores, and total surgical bleeding volume between the groups. Multivariate analysis revealed that Caprini score (the values of OR, 95% CI, and P are 1.962, 1.124–3.424, and 0.018, respectively) and total surgical bleeding volume (the values of OR, 95% CI, and P are 1.010, 1.002–1.018, and 0.017, respectively) were risk variables contributing to DVT occurrence. The area under the receiver operating characteristic curve was 0.918 (95% CI, 0.821–0.988). The calibration curve showed good prediction accuracy.

Conclusion: The Caprini score and total surgical bleeding volume are meaningful self-reliant risk variables contributing to DVT occurrence in postoperative participants with SICH. We have created a straightforward and efficient model to predict early DVT post-SICH surgery. This model serves as a valuable clinical tool for evaluating individual risk and enhancing decision-making processes.

Keywords: spontaneous intracerebral hemorrhage, perioperative postoperative period, lower extremities deep vein thrombosis, caprini score, total surgical bleeding volume

Introduction

The acute kind of stroke known as spontaneous intracerebral hemorrhage (SICH) has a high rate of illness and fatality. The global incidence of SICH is approximately 10 to 30 cases per 100,000 population per year, and a monthly fatality rate can reach a peak of 50%.[1–3] The pathogenesis of SICH involves risk factors such as hypertension and cerebral amyloid angiopathy, which can cause hemorrhage by rupturing small blood vessels in the brain.[4] Various surgical treatment strategies, such as craniotomy and minimally invasive techniques, have been used to reduce intracerebral pressure and remove hematomas. However, the long-term outcome of these approaches remains controversial.[5,6] Post-surgical complications may include rebleeding, cerebral oedema, brain herniation, infections such as surgical site infection and meningitis, hematoma sclerosis, seizures, neurological deficits, cognitive decline, and lower extremity deep vein thrombosis (DVT).

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According to the latest research, the fatality rate for lower extremity DVT spans from 9 to 19%, and the prevalence ranges between 5–21%.[7–9]

However, for patients with SICH, particularly those undergoing surgical intervention, the incidence may differ. Current literature suggests that the DVT prevalence in neurosurgical ICU patients or patients with intracerebral hemorrhage ranges from 3% to 40%.[10–13] The formation of DVT is influenced by Virchow's triad, which includes altered hemodynamics, endothelial damage to the vasculature, and a hypercoagulable state of the blood. Genetic factors like the clotting factor V Leiden mutation and acquired variables like pregnancy and extended bed rest raise the chance of developing DVT.[14,15] The diagnosis of DVT relies on D-dimer testing and compression ultrasonography. The latter confirms the presence of a thrombus by assessing the compressibility of vein.[16] The serious adverse prognosis of DVT includes pulmonary embolism. This condition can be caused by the migration of the thrombus to the pulmonary vasculature, leading to a fatal obstruction of blood flow.[17] Therefore, early diagnosis and prompt treatment are essential to prevent DVT and its serious complications. This not only improves participants' quality of life but also significantly reduces healthcare costs. Early intervention and accurate prediction of the risk of DVT are crucial to reducing the severity of its consequences. This helps to implement personalized treatment plans and improve the effectiveness and safety of treatment.

Some of the commonly used methods to diagnose DVT include imaging tests such as venous ultrasound and venography.[18–20] Although these techniques have a certain degree of specificity and sensitivity, they cannot be used for early prediction of the occurrence of perioperative DVT after surgery. Nomogram models employ various clinico-pathological parameters to generate detailed information that can influence clinical management and inform clinicians about a patient's progression. The models are intuitive and straightforward, allowing for the assessment of high-risk patient prognosis by calculating a total score. These models are widely adopted in clinical environments for predicting disease progression. Despite the development of numerous nomogram models to estimate the incidence and risk of various diseases, to our knowledge, few have been used specifically for predicting early DVT following SICH surgery. This study retrospectively analyzed clinical data and imaging characteristics of participants after neurosurgical SICH and investigated possible risk variables contributing to DVT in the postoperative period, incorporating the use of nomogram models to predict early DVT.

Method

Study Participants

The clinical information of 96 participants who had SICH surgery at the Second People's Hospital of Wuhu between October 2021 and March 2024 was examined in this retrospective analysis. Participants were categorized into two groups: those who developed DVT within one week post-surgery (DVT group) and those who did not (non-DVT group). Inclusion Criteria: 1. Participants diagnosed with SICH who underwent surgical intervention; 2. Diagnosis of DVT in the DVT group confirmed by lower extremities vascular ultrasound according to established criteria; 3. Early DVT examination performed within the perioperative period, specifically within 7 days post-surgery; 4. Availability of complete clinical data without any missing information. Exclusion Criteria: 1. Participants with abnormal coagulation function; 2. Presence of malignant tumors; 3. Evidence of DVT in preoperative assessments; 4. History of pulmonary embolism or previous lower extremities DVT; 5. Complications involving cardiovascular, respiratory, or other critical systemic illnesses. The Second People's Hospital of Wuhu's institutional review board gave this study its ethical clearance (IRB number: 2022028).

Data Collection and Variables

Data collected encompassed demographic information, specifically age and gender, clinical characteristics such as the site of cerebral hemorrhage, diabetes status, perioperative details (operation time, total surgical bleeding volume, intracerebral hematoma volume), subsequent evaluations (blood coagulation status, blood chemistry, and hematologic parameters), and postoperative management (use of anticoagulants, thrombosis risk scores, including the Autar and Caprini scores).

In our institution, standard postoperative care for patients with SICH includes routine mechanical DVT prophylaxis with pneumatic compression devices, which are consistently applied in the postoperative period as a primary preventative measure. Pharmacological prophylaxis, such as low molecular weight heparin or other anticoagulants, is not routinely administered due to the potential risk of exacerbating hemorrhage. In select cases where thromboembolic risk is high and the risk of rebleeding is considered minimal, anticoagulation may be initiated following a careful risk-benefit assessment.

Surgical evacuation is generally recommended for patients with hematoma volumes exceeding 30 mL or in cases where there is evidence of elevated intracranial pressure or impending brain herniation. However, patients with smaller hematomas (10–20 mL) may also undergo evacuation if the hemorrhage is located in functionally critical brain regions or causes significant neurological impairment. This decision is made on a case-by-case basis, reflecting the individualized nature of patient management in our institution.

To minimize selection bias and ensure comprehensive DVT detection, all patients in this study underwent routine lower extremity venous ultrasonography during the first postoperative week, regardless of clinical suspicion. This systematic screening protocol allowed for accurate and consistent identification of DVT across the study cohort, avoiding reliance solely on clinical signs and symptoms, which may underrepresent the true incidence of DVT.

Nomogram Model Development and Validation

To develop a nomogram model for predicting early postoperative DVT in SICH patients, we first conducted multivariate logistic regression analysis to identify significant risk factors. We constructed the nomogram by assigning scores to each predictor based on their regression coefficients. The total score for each patient, representing their cumulative risk, was calculated by summing these individual scores. The model's predictive performance was assessed using receiver operating characteristic (ROC) curve analysis, and internal validation was performed with 1000 bootstrap resampling iterations to ensure reliability. Calibration plots were generated to compare predicted probabilities with observed outcomes, confirming the model's accuracy.

Statistical Analysis

We utilized IBM SPSS (version 27.0) and R (version 4.4.0) for all statistical analyses. Clinical variables were summarized as categorical variables, reported as counts and percentages, while continuous variables were presented as means with standard deviations or medians with interquartile ranges, assuming a Gaussian distribution. Continuous variables were assessed using the two-sample *t*-test, and categorical variables were assessed using the chi-square test to assess the frequency distribution and proportions of discrete parameters. Statistical significance was defined as a p-value of less than 0.05. Factors with a p-value < 0.05 from univariate logistic regression (ULR) related to non-survival were included in multivariable logistic regression (MLR) analysis to identify independent risk factors. The performance of the nomogram was assessed using ROC curves and 1000 bootstrap replications.

Results

Analysis of Demographic and Clinical Features

There were 46 participants in the DVT category and 50 participants in the negative-DVT category who made up the research population. Upon examination of the demographic and clinical data, no statistically meaningful differences were found between the categories with respect to gender, blood pressure readings, blood pressure diagnoses, Glasgow Coma Scale (GCS) results, National Institutes of Health Stroke Scale (NIHSS) results, length of surgery, or use of pneumatic compression devices in the postoperative phase (that is, p is greater than 0.05, Table 1).

Univariate Evaluation of Perioperative DVT Risk Factors

The univariate analysis revealed significant variations in risk variables with the DVT category of the negative-DVT category. Table 1 displays the differences that were observed, including age (value of p is 0.005), D-dimer concentrations (p less than 0.001), fibrinogen degradation product levels (p<0.001), Caprini hazard analysis results (value of p is 0.001), and total surgical bleeding volume (value of p is 0.009).

Table 1 Characteristics of the Study Population

Variables	Total (n=96)	DVT group (n=46)	Non-DVT group (n=50)	X^2/t/Z	P-value
Age [years, Median (P25, P75)]	63.5 (55.75, 72.0)	67.5 (59.0, 76.3)	58.0 (53.0, 67)	2.881	**0.005**
Gender, n(n%)					
Male	46 (47.9)	19 (41.3)	27 (54.0)	23.04	0.148
Female	50 (52.1)	27 (58.7)	23 (46.0)		
Diabetes, n(n%)					
Yes	8 (8.3)	4 (8.7)	4 (8)	0.000	1.000
No	88 (91.7)	42 (91.3)	46 (92)		
Hypertension, n(n%)					
Yes	69 (71.8)	35 (76.1)	34 (68)	0.427	0.514
No	30 (31.2)	11 (23.9)	16 (32)		
GCS score [points, M (P25, P75)]	8 (6, 11)	8 (6, 11)	9 (6, 10.75)	−0.147	0.886
NIHSS score [points, M (P25, P75)]	30 (21.5, 35.0)	30 (25, 35)	30 (20.5, 35)	0.297	0.762
Operation duration [minutes, Median (P25, P75)]	190 (135, 240)	193.5 (143.8, 251.4)	177.6 (120.0, 240.0)	−1.232	0.218
Intracerebral hematoma volume [mL, Median (P25, P75)]	30 (20, 45)	25.0 (10.0, 40.0)	40.0 (20.0, 50.0)	−1.945	0.052
Total surgical bleeding volume [mL, Median (P25, P75)]	180.0 (100.0, 200.0)	200.0 (100.0, 287.5)	150.0 (56.25, 200.0)	2.766	**0.007**
Complications one week after surgery					
Pneumonia, n(n%)					
Yes	63 (65.6)	31 (67.4)	32 (64.0)	0.253	0.615
No	33 (34.4)	15 (32.6)	18 (36.0)		
Pleural effusion, n(n%)					
Yes	77 (80.2)	38 (82.6)	39 (78.0)	0.640	0.424
No	19 (19.8)	8 (17.4)	11 (22.0)		
New cerebral infarction, n(n%)					
Yes	3 (3.1)	2 (4.4)	1 (2.0)	0.009	0.926
No	93 (96.9)	44 (95.6)	49 (98.0)		
Limb paralysis postoperation, n(n%)					
Yes	59 (61.5)	27 (58.7)	32 (64.0)	0.285	0.594
No	37 (38.5)	19 (41.3)	18 (36.0)		
Special treatment one week after surgery					
Central venous catheter postoperation, n(n%)					
Yes	68 (70.8)	33 (78.6)	35 (71.4)	0.291	0.589
No	28 (29.2)	13 (21.4)	15 (28.6)		
Head drainage tube placement postoperation, n(n%)					
Yes	71 (74.0)	37 (80.4)	34 (68.0)	1.923	0.165
No	25 (26.0)	9 (19.6)	16 (32.0)		
Secondary surgery, n(n%)					
Yes	4 (4.2)	3 (6.5)	1 (2.0)	0.356	0.551
No	92 (95.8)	43 (93.5)	49 (98.0)		
Tracheostomy, n(n%)					
Yes	57 (59.4)	32 (69.6)	25 (50.0)	3.802	0.051
No	39 (40.6)	14 (30.4)	25 (50.0)		
Respiratory support with mechanical ventilation, n(n%)					
Yes	93 (96.9)	44 (95.7)	49 (98.0)	0.005	0.941
No	3 (3.1)	2 (4.3)	1 (2.0)		
Anticoagulation therapy, n(n%)					
Yes	13 (13.5)	4 (8.7)	9 (18.0)	1.772	0.183
No	83 (86.5)	42 (91.3)	41 (82.0)		
Diuretics use, n(n%)					

(*Continued*)

Table 1 (Continued).

Variables	Total (n=96)	DVT group (n=46)	Non-DVT group (n=50)	X^2/t/Z	P-value
Yes	20 (20.8)	8 (17.4)	12 (24.0)	0.634	0.426
No	76 (79.2)	38 (82.6)	38 (76.0)		
Caprini score [points, M (P25, P75)]	11.0 (10.0, 14.0)	13.5 (11.25, 14.75)	10.0 (9.0, 11.5)	3.35	**0.001**
Autar score [score, M (P25, P75)]	18.0 (17.0, 20.0)	19.0 (17.0, 20.0)	18.0 (16.5, 19.5)	0.80	0.424
Laboratory Indicators					
Albumin [g/L, mean±SD]	33.4±4.0	32.6±3.6	34.1±4.3	1.894	0.061
Highdensity lipoprotein [mmol/L, Median (P25, P75)]	0.9 (0.8, 1.1)	0.9 (0.7, 1.2)	0.9 (0.8, 1.1)	−0.572	0.567
Lowdensity lipoprotein [mmol/L, Median (P25, P75)]	2.5 (2.1, 3.0)	2.4 (2.1, 3.1)	2.5 (2.1, 3.1)	−0.055	0.956
Calcium ion concentration [mmol/L, Median (P25, P75)]	2.2 (2.1, 2.3)	2.1 (2.0, 2.3)	2.2 (2.1, 2.3)	−1.944	0.052
Procalcitonin [ng/mL, Median (P25, P75)]	0.24 (0.13, 0.44)	0.2 (0.1, 0.4)	0.2 (0.1, 0.5)	−0.290	0.772
C reactive protein [mg/L, Median (P25, P75)]	68.6 (23.0, 129.0)	51.2 (16.6, 121.0)	94.3 (28.2, 133.0)	−1.234	0.217
Interleukin 6 [pg/mL, Median (P25, P75)]	30.7 (21.2, 68.8)	29.8 (18.6, 79.6)	36.2 (26.8, 67.1)	−0.460	0.645
B-type Natriuretic Peptide [pg/mL, Median (P25, P75)]	100.7 (62.4, 250.6)	100.5 (56.5, 202.8)	165.1 (60.7, 289.7)	−0.680	0.497
Red blood cells [10^12/L, Median (P25, P75)]	3.6 (3.2, 4.3)	3.6 (3.1, 4.0)	3.7 (3.3, 4.5)	−1.539	0.124
Platelets [10^9/L, Median (P25, P75)]	187.0 (123.0, 254.0)	179.0 (110.0, 235.5)	204.0 (126.8, 284.3)	−1.565	0.118
White blood cells [10^9/L, Median (P25, P75)]	9.3 (7.2, 11.4)	9.1 (7.3, 11.2)	9.5 (7.1, 11.8)	−0.194	0.846
Prothrombin time [seconds, Median (P25, P75)]	13.7 (12.1, 14.1)	13.8 (13.3, 14.3)	13.6 (13.1, 14.1)	−1.360	0.174
Prothrombin activity [%, Median (P25, P75)]	95.0 (88.0, 104.0)	93.0 (87.0, 101.5)	97.0 (89.5, 105.0)	−1.454	0.146
International Normalized Ratio of Prothrombin Time [Median (P25, P75)]	1.0 (1.0, 1.1)	1.0 (1.0, 1.1)	1.1 (1.0, 1.1)	−1.523	0.128
Activated partial thromboplastin time [seconds, Median (P25, P75)]	36.2 (32.8, 40.1)	36.5 (33.2, 40.0)	36.0 (32.7, 40.6)	−0.098	0.922
Thrombin time [seconds, Median (P25, P75)]	16.5 (15.5, 17.1)	16.5 (15.6, 17.2)	16.4 (15.3, 17.2)	−0.435	0.663
D-dimer [μg/mL, Median (P25, P75)]	2.69 (1.8, 5.8)	3.8 (2.5, 10.31)	2.0 (1.2, 4.0)	4.079	**<0.001**
Fibrinogen [g/L, Median (P25, P75)]	5.8 (4.6, 7.1)	5.5 (4.3, 6.8)	6.2 (4.8, 7.2)	−1.953	0.051
Fibrinogen degradation products [μg/mL, Median (P25, P75)]	11.25 (6.1, 20.1)	15.9 (9.8, 32.5)	8.3 (4.6, 13.6)	−3.916	**<0.001**

Notes: Bold font indicates statistical significance.
Abbreviations: DVT, deep vein thrombosis; GCS, Glasgow Coma Scale; NIHSS, National Institutes of Health Stroke Scale.

Multivariate Analysis and Predictive Accuracy of Risk Factors

Using a multivariate logistic regression model, the analysis shows that in participants undergoing surgery for SICH, the Caprini score and the total surgical bleeding volume both independently function as significant risk variables contributing to DVT (p less than 0.05, Table 2).

Development and Validation of a Nomogram Model

Multivariate logistic regression identified the Caprini score and total surgical bleeding volume as potential predictors. A prognostic model comprising these two factors was then developed to assess the risk of early deep vein thrombosis in patients after SICH surgery. A nomogram was created to visually represent this predictive model (Figure 1). For example, for a patient with a Caprini score of 12 and a total surgical bleeding volume of 300 mL following SICH surgery, the total score calculated from the nomogram would be 80 (30 points for the Caprini score and 50 points for the bleeding volume). Based on this total score, the predicted risk of developing DVT within the first week postoperatively is approximately 88%.

Table 2 Multivariate Logistic Regression Analysis of the Influencing Factors of Lower Limb Deep Vein Thrombosis in Patients with Spontaneous Intracerebral Hemorrhage Undergoing Surgical Treatment

Variables	Regression Coefficient	SEM	Wald χ2	P-value	Odds Ratio (95% CI)
Age	−0.0154	0.049	0.312	0.755	0.985(0.894–1.086)
Total surgical bleeding volume	0.0098	0.004	2.393	**0.017**	1.01(1.002–1.018)
D-dimer	0.0705	0.387	0.182	0.856	1.073(0.503–2.292)
Fibrinogen degradation products	0.0183	0.088	0.207	0.836	1.018(0.857–1.21)
Caprini score	0.6738	0.284	2.372	**0.018**	1.962(1.124–3.424)

Note: Bold font indicates statistical significance.

The predictive accuracy of the model for early DVT in post-SICH patients was assessed by ROC curves, which showed an area under the curve of 0.918 (95% CI, 0.821–0.988) (Figure 2). The reliability of the internal calibration was further confirmed by internal validation with 1000 bootstrap replications, showing a high degree of consistency (Figure 3).

Discussion

DVT represents a significant postoperative complication, potentially leading to local pain, gait impairment, and severe outcomes such as pulmonary embolism, post-thrombotic syndrome, or even death. This study focuses on identifying risk factors associated with DVT during the perioperative period following surgery for SICH, which is critical for early detection and effective prevention. Moreover, we developed a simple, effective, and clinically valuable model to predict the probability of early DVT in individual post-SICH patients. With this model, clinicians can quickly calculate the risk of DVT in individual patients, which may help to making management decisions.

Our findings reveal that both total surgical bleeding volume and the Caprini score are independent risk variables for DVT. During surgery, substantial bleeding markedly raises the likelihood of lower extremity DVT.

Studies have demonstrated that significant surgical bleeding can lead to a reduction in effective circulating blood volume, which is critical in the pathophysiology of postoperative DVT following SICH.[21,22] This decrease in blood volume triggers the body to activate various coagulation mechanisms to stabilize hemostasis.[23,24] Specifically, the reduced volume stimulates the release of key coagulation factors, including fibrinogen, Factor VIII, and von

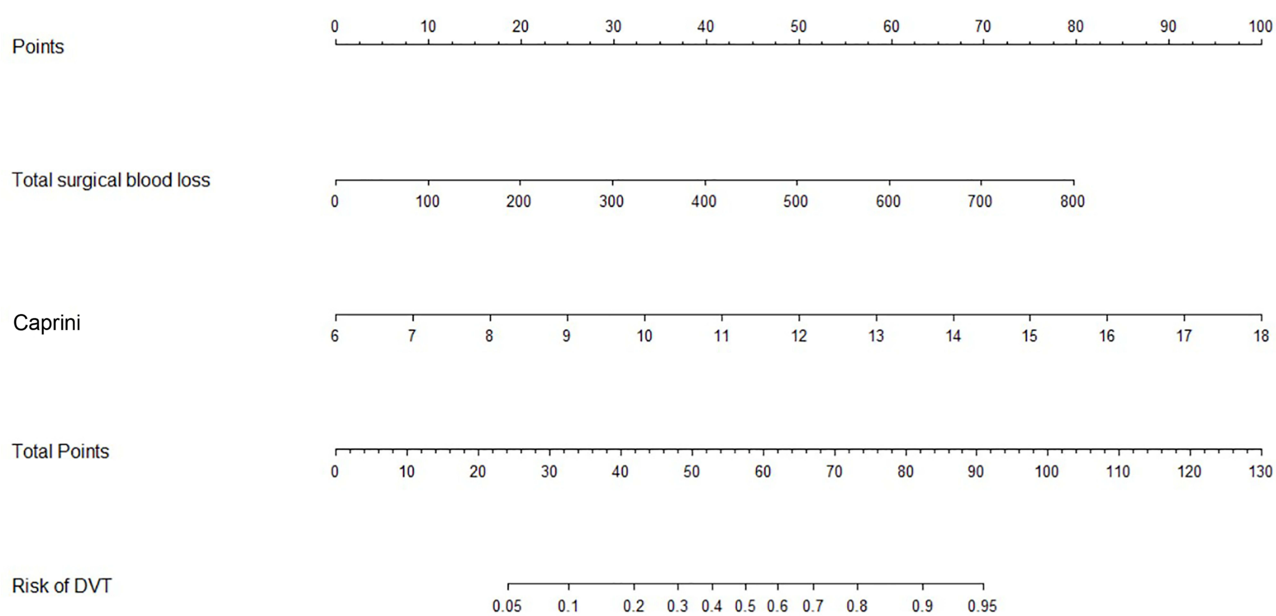

Figure 1 The nomogram for predicting the risk of early deep vein thrombosis in patients after spontaneous intracerebral hemorrhage surgery.

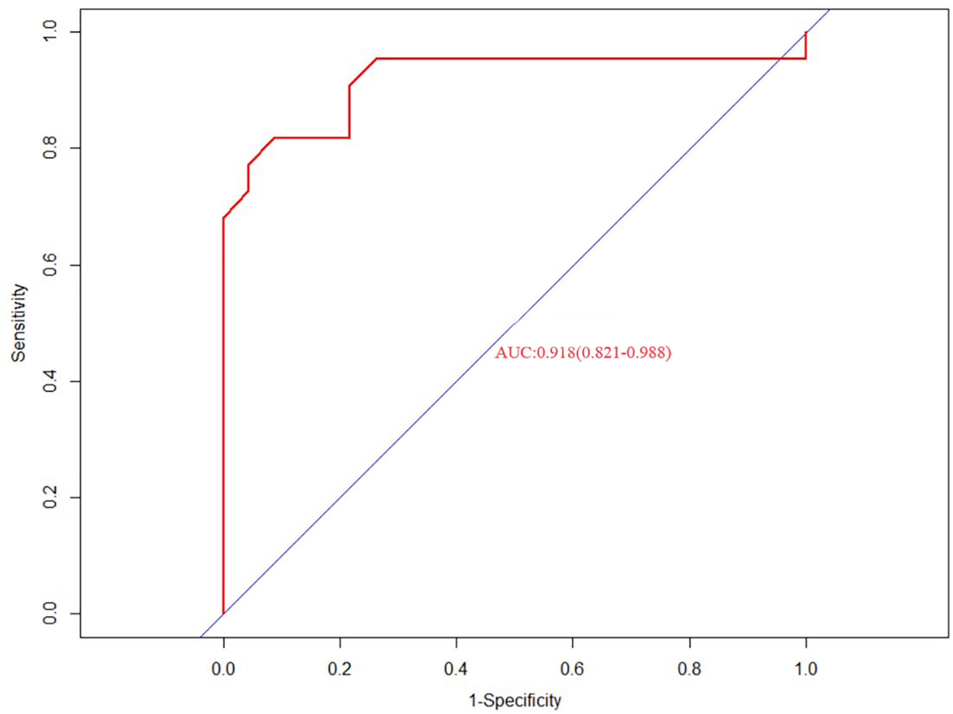

Figure 2 Receiver operating characteristic curve for the nomogram model. AUC, area under curve.

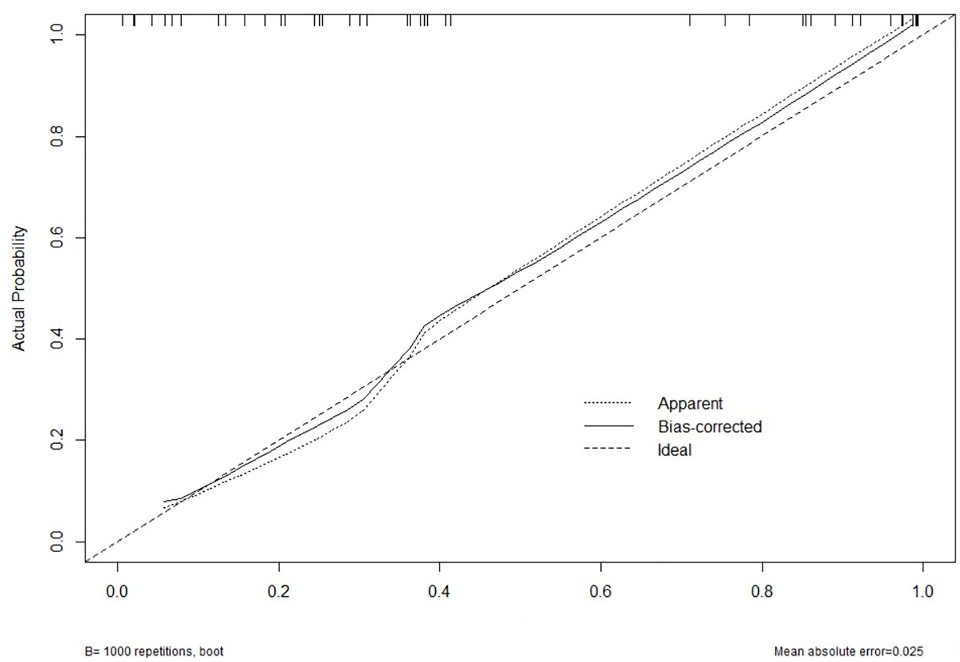

Figure 3 Calibration curves of the predicted nomogram. The dashed line represents the original performance, and the solid dashed line represents the performance during internal validation by bootstrapping (B = 1000 repetitions).

Willebrand factor, which enhance platelet aggregation and promote coagulation.[25–27] As noted by Gangireddy et al[28] this change not only increases platelet activity but also fosters a hypercoagulable state, significantly raising the probability of postoperative DVT. Furthermore, the inflammatory response triggered by surgical trauma leads to the release of cytokines, such as IL-6 and TNF-alpha, further contributing to a pro-thrombotic environment. These factors collectively disrupt blood homeostasis, particularly in scenarios where patients experience prolonged immobility or compression of the lower extremities. Such conditions exacerbate blood stagnation, increasing the risk of venous thrombosis. Zhang et al[29] showed that procoagulant factors released by activated monocytes and macrophages in the inflammatory response triggered by surgical wounds and tissue injury enhance blood coagulation. They also found that a rise in inflammatory factors such as IL-6 and TNF-alpha is closely linked with an elevated susceptibility to DVT. Matthay et al[21] stated that reduced activity during postoperative recovery, particularly prolonged bed rest following heavy bleeding, leads to a slowing of venous blood flow in the lower extremities. This is an important factor in the formation of DVT. Therefore, effective thromboprophylaxis, which includes the use of anticoagulant medications, early and appropriate physical activity, maintenance of adequate blood flow, and wearing compression stockings to promote venous return, is particularly critical for surgical participants who may experience heavy bleeding. This approach effectively lowers the likelihood of DVT after surgery. Interestingly, preoperative hemorrhage volume was not found to be a significant predictor of postoperative DVT in our analysis. This contrasts with existing literature linking SICH volume with mortality and poor outcomes. One possible explanation for this finding is that our study focused on early postoperative DVT risk, which may be more closely associated with perioperative factors, such as immobility and inflammatory response, rather than the initial hemorrhage volume itself. Additionally, the limited sample size may have constrained our ability to detect a significant relationship between these variables. Future studies with larger sample sizes may help to clarify this potential association.

Our investigation confirms the usefulness of the Caprini score, particularly when combined with the evaluation of total surgical bleeding, in enhancing the prediction accuracy for DVT risk. The ROC curve analysis confirms the high predictive value of this nomogram model, suggesting its potential to guide the need for prophylactic interventions. The Caprini scoring system is a widely recognized tool used to assess a patient's potential risk of developing DVT. Our study compared the Caprini scoring system with the Autar scoring system and found that the Caprini scoring system is more suitable for assessing DVT risk in the perioperative period after SICH. The Caprini scoring system includes a variety of clinical and non-clinical factors, such as age, surgical history, hormone use, etc., by combining these risk factors.[30] The Caprini results offer one numerical hazard evaluation for each patient by combining these risk variables. Participants are categorized into various hazard levels according to their scores, with higher scores indicating an increased likelihood of DVT occurrence.[31] Research has demonstrated that surgical participants with scores of 5 and above have a significantly increased risk of DVT. Pannucci et al[32] study developed a quantitative risk score for each patient by combining multiple risk variables, which can guide the need for anticoagulant therapy in clinical practice. Furthermore, Bahl et al[33] validated the accuracy of the Caprini scoring method for assessing the hazard of venous blood clotting through a retrospective study. Similarly, Obi et al[34] confirmed the validity of this scoring system for critically ill surgical participants. Gould et al[35] recommended the use of the Caprini scoring system to guide the use of antithrombotic therapy by non-orthopaedic surgical participants. These studies support the validity of the Caprini scoring system as a tool for predicting and preventing DVT. Although the area under the ROC curve was 0.918, which suggests excellent predictive accuracy, we recognize that this value may be influenced by the relatively small sample size and the limited number of risk factors included in the model. To mitigate potential bias, all patients in the study underwent routine lower extremity ultrasound screening, regardless of their Caprini score or clinical suspicion for DVT. This uniform approach ensures comprehensive detection of DVT, which reduces the likelihood of selective bias. Nevertheless, the model's performance requires further confirmation through external validation on larger and more diverse cohorts to fully assess its generalizability and robustness.

Our study demonstrates that the integration of the Caprini score and total surgical bleeding volume into a nomogram model significantly enhances the ability to predict early DVT in postoperative SICH patients. The model's high area under the ROC curve indicates strong predictive accuracy. Analyzing the results, we observe that the Caprini score, widely used for assessing DVT risk, gains additional predictive strength when combined with total surgical bleeding volume. This combination likely captures both pre-existing risk factors and perioperative physiological stress, providing a comprehensive risk assessment. This enhanced prediction model not only supports proactive clinical decision-making but also underscores the importance of meticulous intraoperative management and postoperative monitoring. By integrating these significant risk factors, our nomogram offers a pragmatic approach to mitigating DVT risks in SICH patients, thereby improving patient care and optimizing resource allocation in clinical practice. While the nomogram model demonstrated promising internal validation results, we acknowledge the need for external validation to confirm its generalizability. Future studies should aim to validate this model in larger, multi-center cohorts to ensure its applicability across diverse clinical settings. Conducting such validation will be crucial for establishing the nomogram as a reliable tool for predicting early DVT in SICH patients.

To minimize selection bias and ensure accurate assessment of DVT incidence, all patients in this study underwent routine lower extremity ultrasound screening, regardless of their clinical suspicion for DVT. This standardized approach reduced the risk of underdiagnosis and provided a comprehensive evaluation of DVT across the entire cohort. Furthermore, the consistent use of pneumatic compression devices as mechanical prophylaxis in all patients ensured uniform prevention measures, thereby reducing the risk of DVT without increasing hemorrhagic complications or introducing treatment-related biases.

Despite the novel insights provided by this study, several limitations must be addressed. First, the relatively small sample size constrains the statistical power of the analysis and raises concerns about overfitting, particularly in light of the high predictive accuracy indicated by the ROC curve. This suggests that while the model shows promise, its performance may not be robust when applied to larger or more diverse populations, thus warranting further validation. Second, the single-center, retrospective design limits the generalizability of the findings. Retrospective studies are inherently vulnerable to biases in data selection and completeness, which may lead to unrecognized confounding effects. The exclusion of patients with pre-existing coagulopathies or previous thrombotic events introduces additional selection bias, potentially skewing the results toward a healthier subset of patients. Furthermore, while all patients underwent routine lower extremity ultrasound screening, the reliance on this single modality may have underestimated the true incidence of DVT, particularly for asymptomatic cases that might not have been detected. The focus on specific variables, such as the Caprini score and total surgical bleeding volume, also highlights the risk of omitting other relevant factors that could influence DVT risk, potentially limiting the comprehensiveness of the predictive model. Lastly, the lack of external validation represents a critical limitation. Although internal validation demonstrated strong predictive performance, external validation in a larger, multi-center cohort is essential to confirm the model's applicability across different clinical settings. Prospective studies with diverse populations will be needed to refine the model and ensure its clinical utility.

Conclusion

This study found that total surgical bleeding volume and the Caprini score were independent risk variables for DVT in the lower extremities after SICH surgery. The findings underscore the meaning of early DVT hazard evaluation in SICH participants to enable appropriate preventive measures and reduce the risk of postoperative complications. The nomogram model developed in this study offers a convenient method for assessing individual early DVT risk in patients with SICH after surgery, thereby aiding in preventive measures. Future research should address these limitations through larger, multi-center prospective studies to enhance the understanding of DVT risks and refine prevention strategies in SICH participants.

Abbreviations

AUC, Area Under Curve; DVT, Deep Vein Thrombosis; GCS, Glasgow Coma Scale; MLR, Multivariable Logistic Regression; NIHSS, National Institutes of Health Stroke Scale; ROC, Receiver Operating Characteristic; SICH, spontaneous Intracerebral Hemorrhage; ULR, Univariate Logistic Regression.

Data Sharing Statement

All data used in this study are included in the article.

Ethics Approval and Informed Consent

This study was approved by the Second People's Hospital of Wuhu's institutional review board (IRB number: 2022028). Written informed consent was obtained from all participants prior to their inclusion in the study. Participants were informed about the purpose of the study, procedures involved, potential risks, and their right to withdraw at any time without any consequences. All data were anonymized to comply with the provisions of personal data protection legislation. This study adhered to the tenets of the Declaration of Helsinki.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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