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Risk factor analysis and nomogram model of DVT in hip fracture patients at hospital admission

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Abstract

Background The incidence of deep vein thrombosis (DVT) on the first day of hospitalization in patients with hip fractures is as high as 42%, significantly impacting perioperative safety and, in severe cases, leading to patient mortality. This study aims to develop a diagnostic model based on the available demographic variables, comorbidities, and laboratory test results at admission in patients with hip fractures, and to evaluate its diagnostic performance.

Methods This study retrospectively collected clinical data from 238 patients with hip fractures admitted to the Third Affiliated Hospital of Chongqing Medical University between January 2019 and December 2021. The collected clinical data included demographic variables, medical history, comorbidities, laboratory test results, and Caprini scores. All patients were diagnosed with deep vein thrombosis (DVT) using ultrasonography. The multivariate logistic regression analysis was performed to identify risk factors for lower extremity DVT in hip fracture patients upon admission. The diagnostic performance of the model was evaluated using receiver operating characteristic (ROC) curve analysis. Additionally, the diagnostic effectiveness of different indicators was compared using the integrated discrimination improvement (IDI), net reclassification improvement (NRI), and decision curve analysis (DCA). A nomogram was further developed to provide a visual representation of the multivariate logistic regression model.

Results The multivariate logistic regression model identified female gender, cardiac arrhythmia, intertrochanteric fractures, fracture duration before admission (≥ 48 h), aPTT, and Caprini scores as factors associated with the occurrence of thrombosis upon admission in patients with hip fractures. Leave-one-out cross-validation demonstrated that the diagnostic model achieved an accuracy (Acc) of 76.47%, a sensitivity (Sen) of 81.03%, and a specificity (Spe) of 75.00%. When the risk probability was < 0.2, the thrombosis rate was 7.64%, whereas it increased significantly to 80.65% when the risk probability exceeded 0.6. Compared to the traditional Caprini score, the model showed an improvement in AUC (AUC difference = 0.072, 95% CI = 0.028–0.117). The Integrated Discrimination Improvement (IDI = 0.131, 95% CI = 0.074–0.187), Net Reclassification Improvement (NRI = 0.814, 95% CI = 0.544–1.084), and Decision Curve Analysis (DCA) at threshold probabilities of 0.10–0.22 and 0.35–1.00 demonstrated that the model outperformed the traditional Caprini score in diagnosing thrombosis. Finally, the diagnostic model constructed through multivariate logistic regression was visualized using a nomogram. After 2,000 bootstrap resampling

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validations, the model's C-index was 0.855, and the bias-corrected C-index was 0.836, indicating good discriminatory ability.

Conclusions This study developed a nomogram model for deep vein thrombosis (DVT) that significantly outperforms the traditional Caprini score. The model can assist clinicians in rapidly identifying and screening high-risk patients with hip fractures for DVT, providing a valuable reference for timely preventive and therapeutic interventions.

Keywords Hip fracture, Venous thrombosis, Deep vein thrombosis, Nomogram

Introduction

Hip fracture mainly occurs as an osteoporotic or fragility fracture [1].There are approximately 1.7 million hip fractures each year, and this number is projected to exceed 6 million worldwide by 2050 [2]. Deep vein thrombosis (DVT) is common in patients with hip fracture [3, 4]. The incidence of DVT in patients with hip fracture ranges from 16.6–34.98% [5–10].Moreover, the incidence of deep vein thrombosis on the first day after admission in patients with hip fractures can reach as high as 42% [11]. The formation of thrombisis not only affects the perioperative safety of hip fracture patients [4, 12, 13], but also increases medical expenses and even prolongs the length of hospitalization [14].Clinical studies have mainly addressed preoperative, postoperative and perioperative DVT in patients with hip fracture; additionally, venography and ultrasound are not suitable for most elderly individuals with hip fracture. As a result, many patients with DVT of the lower extremities are not examined and diagnosed in a timely manner after admission. Currently, there are few reports on the risk factors for the formation of DVT in patients with hip fracture at admission, and there is also a lack of an intuitive and visual nomogram model to assess the risk of DVT. The aim of this study was to analyse the risk factors for DVT in hip fracture patients at admission and to construct a visual nomogram model based on the risk factors to provide a theoretical basis for clinical medical personnel to easily and visually assess the risk of DVT in such patients.

Patients and methods

Patients and study design

This was a retrospective study.In this study, the data of 244 patients with hip fracture admitted to the Orthopaedic and Trauma Center of the Third Affiliated Hospital of Chongqing Medical University between January 2019 and December 2021 were retrospectively analysed; ultimately, the data of 238 patients were included in the analyses.This retrospective study was approved by the Institutional Review Board (IRB).

Inclusion criteria

(1) Age ≥ 18 years;

(2) Patients diagnosed with hip fractures (femoral neck fracture, intertrochanteric fracture, or subtrochanteric fracture) confirmed by imaging examinations (X-ray, CT, or MRI).

Exclusion criteria

(1) History of deep vein thrombosis (DVT) in the lower extremities;
(2) Use of anticoagulant medications prior to admission;
(3) Long-term use of contraceptives or hormonal medications;
(4) Failure to complete ultrasound examination within 24 h of admission;
(5) Prolonged bedridden status prior to hip fracture;
(6) Emergency surgery upon admission.

All patients underwent routine ultrasound of the deep veins of the lower extremities within 1 day of hospitalization.Color Doppler ultrasonography was performed by experienced radiologists in a dedicated ultrasound room. All results were reviewed by senior radiologists, and re-examinations were conducted in cases of differing opinions.The diagnosis of DVT was based on the Robinov criteria, which include the following four components: (1) a persistent filling defect with a constant thrombus appearance, often with well-defined boundaries; (2) abrupt termination of an opaque column at a fixed position above or below the obstruction; (3) non-filling of the entire deep venous system or part of it, which is abnormal and typically caused by phlebitis when appropriate techniques are used; and (4) flow diversion representing collateral circulation, corresponding to the aforementioned non-filling.DVT was divided into three types: central, peripheral, and mixed. All patients were fitted with compression stockings upon admission and received intermittent pneumatic compression therapy starting from admission, except during periods of external fixation, skeletal traction, or cast immobilization, or in cases where these mechanical prophylactic devices were contraindicated.

All clinical cases met the inclusion and exclusion criteria.Collected data included demographic variables and clinic characteristics(age, sex, BMI, alcohol consumption, cigarette smoking, Complications and medication

(diabetes, hypertension, coronary heart disease, stroke, malignant tumours, chronic obstructive pulmonary disease, bronchiectasis, cardiac arrhythmias, myocardial infarction, use of anticoagulant medications), Fracture related data (Multiple fractures throughout the bodyand fracture location, injury mechanism, time from fracture to admission, femoral surgery history)andLaboratory Test Results Within 24 h after admission (white blood cell count, red blood cell count, haemoglobin, haematocrit, platelet count, neutrophil count, lymphocyte count, mean platelet volume, platelet distribution width, C-reactive protein, high-sensitivity D-dimer, prothrombin time, aPTT, thrombin time, fibrinogen, total protein level, albumin level) and Caprini scores.

Central DVT referred to a thrombus that occurred in the ilium, the superficial femoral vein and/ or the femoral vein near the knee joint. Peripheral DVT referred to a thrombus that formed in the posterior tibial vein or the peroneal vein at the distal end of the knee. A high-energy injury was defined as an injury where there was a high possibility that multiple organs might be damaged due to mechanisms such as falling more than 4 ft, traffic accident, and direct blow. A low-energy injury was defined as an injury which patients would sustain while falling over slippery ground in a walking or sitting position.The "time from fracture to admission" was defined as the duration (in hours) between the occurrence of the fracture and the patient's initial hospital registration.

Statistical methods

We compared the differences between DVT group and non-DVT group in demographic, medical history, and laboratory test results.Normally distributed continuous variables are expressed as mean ± standard deviation (SD), and comparisons between the DVT and non-DVT groups are performed using the independent samples t-test. For skewed continuous variables, data are presented as median and interquartile range (IQR), with comparisons conducted using the Mann-Whitney U test. Categorical variables are described as frequency and percentage (n, %), and group comparisons are carried out using the chi-square test. Variables with a p-value < 0.05 in univariate analysis are included in the multivariate logistic regression model for thrombosis, with variable selection performed using a stepwise method.

A diagnostic model for thrombosis in fracture patients is developed based on the results of the multivariate logistic regression analysis. Internal validation is conducted using leave-one-out cross-validation, while the Hosmer-Lemeshow test is applied to assess model calibration. The diagnostic performance of the model is evaluated using accuracy, sensitivity, specificity, and the area under the curve (AUC), where values closer to 1 indicate better performance. To compare the diagnostic efficacy of different metrics, integrated discrimination improvement (IDI), net reclassification improvement (NRI), and decision curve analysis (DCA) are employed. A nomogram is constructed to visualize the multivariate logistic regression model, with calibration curves generated through 2000 bootstrap resampling iterations. The concordance index (C-index) is calculated using Harrell's C statistic to assess the nomogram's discriminatory ability.

The nomogram and DCA analyses are performed using R software, while all other statistical analyses are conducted with SAS 9.4 software (Copyright ©2016 SAS Institute Inc, Cary, NC, USA). A p-value < 0.05 is considered statistically significant.

Results

Results of Univariate Analysis of DVT in Hip Fracture patients at Admission

A total of 238 hip fracture patients were included in this study (Fig. 1).The median age of the study population in this research was 76 years (interquartile range: 65–83 years), the DVT group comprised 58(24.37%) patients, and the non-DVT group comprised 180(75.63%) patients.Among them, fracture site in patients as follows : intertrochanter 129(54.20%),inferior intertrochanter 2(0.84%),and femoral neck 113(47.48%) (Table 1);In patients with hip fractures, significant statistical differences (P < 0.05) were observed between the thrombosis group upon admission and the non-thrombosis group regarding age, gender, cardiac arrhythmia, fracture site (intertrochanteric and femoral neck), time from injury to admission, RBC, HGB, HCT, aPTT, TP, ALB, and Caprini scores (Table 1).

Results of Multivariate Logistic Regression Model for DVT in patients with hip fractures at admission

The Hosmer-Lemeshow test for the multivariate logistic regression model yielded a p-value of 0.196, indicating a good model fit. Factors positively associated with thrombosis upon admission in hip fracture patients included: female gender (OR = 2.752, 95% CI = 1.222–6.196), cardiac arrhythmia (OR = 4.757, 95% CI = 1.632–13.869), intertrochanteric fracture (OR = 3.138, 95% CI = 1.383–7.120), time from injury to admission ≥ 48 h (OR = 2.989, 95% CI = 1.206–7.407), and Caprini scores (OR = 1.796, 95% CI = 1.473–2.188). Conversely, activated partial thromboplastin time (aPTT) was negatively associated with thrombosis (OR = 0.822, 95% CI = 0.721–0.937), p < 0.05 (Table 2).

Comparison of diagnostic efficacy for DVT at Admission in patients with hip fractures

A diagnostic model for thrombosis upon admission in hip fracture patients was developed based on a multivariate logistic regression analysis. Thrombosis was

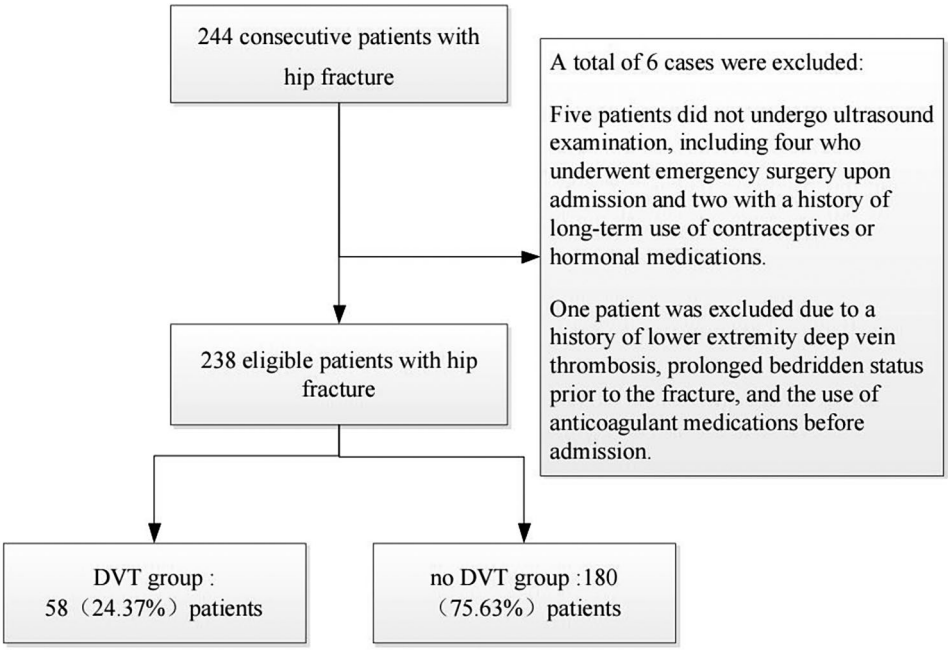

Fig. 1 Schematic illustration of the patient selection criteria

determined when the model probability was greater than or equal to 0.2. Leave-one-out cross-validation revealed that the model achieved an accuracy of 76.47%, a sensitivity of 81.03%, and a specificity of 75.00%. Further risk stratification indicated that among patients with a model probability < 0.2, only 7.64% were diagnosed with thrombosis upon admission. In contrast, the prevalence of thrombosis in patients with a model probability > 0.6 reached 80.65% (Table 3).

The ROC curve comparing the model with Caprini scores for diagnosing thrombosis in hip fracture patients is illustrated in Fig. 2. The model demonstrated an increase in the area under the curve (AUC) by 0.072 compared to Caprini scores (Difference in AUC = 0.072, 95% CI = 0.028–0.117). The model's diagnostic capability for thrombosis improved by 13.1% (IDI = 0.131, 95% CI = 0.074–0.187), and the likelihood of correctly identifying thrombosis increased by 81.4% (NRI = 0.814, 95% CI = 0.544–1.084), $p < 0.05$ (Table 4). Decision curve analysis (DCA) indicated that the standardized net benefit of the model was superior to that of Caprini scores at threshold probabilities ranging from 0.1 to 0.22 and from 0.35 to 1.00 (Fig. 3).

Visualization of the Model for DVT at Admission in patients with hip fractures

The nomogram model was utilized to visually analyze the multivariate logistic regression model (Fig. 4). After performing 2000 bootstrap resampling validations, the diagnostic C-index was found to be 0.855, with a bias-corrected C-index of 0.836, indicating good discrimination. The calibration curve (Fig. 5) demonstrates a strong agreement between the model's predicted risk of thrombosis upon admission and the actual observed risk, with an average absolute error of 0.022.

Discussion

This case-control study included a total of 238 patients with hip fractures, and their clinical data(including demographic variables, comorbidities, and laboratory tests results within 24 h) were retrospectively analyzed. Multivariate analysis identified that female, cardiac arrhythmias, Intertrochanteric fracture, time from injury to admission (≥ 48 h), aPTT, Caprini scores were associated with the risk of deep vein thrombosis (DVT) at the time of admission in patients with hip fractures.Based on the results of the multivariate analysis, a simple, intuitive, and visual nomogram model was developed. This model provides a valuable tool to assist clinicians in rapidly assessing DVT risk upon patient admission, thereby supporting the optimization of treatment decisions and care strategies.

In this study, female sex was a risk factor for DVT in hip fracture patients at admission. Based on a meta-analysis, female sex is a risk factor for preoperative DVT in hip fracture patients [5].Kai Song et al.have reported that female sex is a risk factor for preoperative DVT in patients with intertrochanteric fractures. Therefore, the findings of this study are consistent with the results of previous studies; a potential explanation is genetic differences and hormonal changes after menopause and its associated complications [15, 16].Therefore, in

Table 1 The association between thrombosis during hospital admission and clinical features in patients with hip fracture

Characteristics	Total	Non-DVTgroup($n=180$)	DVTgroup($n=58$)	t/Z/χ^2	*P*
General information					
Age(year), n (%)					
<65	58(24.37)	53(29.44)	5(8.62)	10.320	< 0.001
≥ 65	180(75.63)	127(70.56)	53(91.38)		
Gender, n (%)					
Female	142(59.66)	100(55.56)	42(72.41)	5.180	0.023
Male	96(40.34)	80(44.44)	16(27.59)		
BMI					
Lose weight	35(14.71)	25(13.89)	10(17.24)	1.661	0.646
Normal	126(52.94)	93(51.67)	33(56.90)		
Overweight	59(24.79)	47(26.11)	12(20.69)		
Obesity	18(7.56)	15(8.33)	3(5.17)		
Alcohol consumption, n (%)					
No	202(84.87)	151(83.89)	51(87.93)	0.558	0.455
Yes	36(15.13)	29(16.11)	7(12.07)		
Cigarette smoking, n (%)					
No	186(78.15)	140(77.78)	46(79.31)	0.060	0.806
Yes	52(21.85)	40(22.22)	12(20.69)		
Complications and medication					
Diabetes, n (%)					
No	201(84.45)	154(85.56)	47(81.03)	0.683	0.409
Yes	37(15.55)	26(14.44)	11(18.97)		
Hypertension, n (%)					
No	151(63.45)	116(64.44)	35(60.34)	0.318	0.573
Yes	87(36.55)	64(35.56)	23(39.66)		
Coronary heart disease, n (%)					
No	214(89.92)	161(89.44)	53(91.38)	0.181	0.670
Yes	24(10.08)	19(10.56)	5(8.62)		
Stroke, n (%)					
No	209(87.82)	158(87.78)	51(87.93)	< 0.001	0.975
Yes	29(12.18)	22(12.22)	7(12.07)		
Malignant tumours, n (%)					
No	229(96.22)	172(95.56)	57(98.28)	0.301	0.583
Yes	9(3.78)	8(4.44)	1(1.72)		
Chronic obstructive pulmonary disease, n (%)					
No	215(90.34)	164(91.11)	51(87.93)	0.508	0.476
Yes	23(9.66)	16(8.89)	7(12.07)		
Bronchiectasis, n (%)					
No	235(98.74)	179(99.44)	56(96.55)	1.083	0.298
Yes	3(1.26)	1(0.56)	2(3.45)		
Cardiac arrhythmias, n (%)					
No	214(89.92)	169(93.89)	45(77.59)	12.858	< 0.001
Yes	24(10.08)	11(6.11)	13(22.41)		
Myocardial infarction, n (%)					
No	235(98.74)	179(99.44)	56(96.55)	1.083	0.298
Yes	3(1.26)	1(0.56)	2(3.45)		
Use of anticoagulant medications, n (%)					
No	117(49.16)	91(50.56)	26(44.83)	0.576	0.448
Yes	121(50.84)	89(49.44)	32(55.17)		
Fracture related data					
Multiple fractures throughout the body, n (%)					
No	211(88.66)	160(88.89)	51(87.93)	0.040	0.841
Yes	27(11.34)	20(11.11)	7(12.07)		

Table 1 (continued)

Characteristics	Total	Non-DVTgroup($n=180$)	DVTgroup($n=58$)	t/Z/χ^2	*P*
Fracture location, n (%)					
Left lower extremity	106(44.54)	84(46.67)	22(37.93)	1.355	0.244
Right lower extremity	129(54.20)	93(51.67)	36(62.07)	1.912	0.167
Intertrochanter fracture, n (%)	129(54.20)	88(48.89)	41(70.69)	7.543	0.006
Inferior intertrochanter fracture, n (%)	2(0.84)	2(1.11)	0(0.00)	< 0.001	0.999
Femoral neck fracture, n (%)	113(47.48)	92(51.11)	21(36.21)	3.908	0.048
Injury mechanism, n (%)					
Low energy injury	220(92.44)	167(92.78)	53(91.38)	< 0.001	0.948
High energy injury	18(7.56)	13(7.22)	5(8.62)		
Time from fracture to admission(hour), n (%)					
< 48 h	190(79.83)	149(82.78)	41(70.69)	3.981	0.046
≥ 48 h	48(20.17)	31(17.22)	17(29.31)		
Femoral surgery history, n (%)					
No	214(89.92)	161(89.44)	53(91.38)	0.181	0.670
Yes	24(10.08)	19(10.56)	5(8.62)		
Laboratory Test Results Within 24 h after admission					
WBC ,10^9 /L median (IQR)	7.92(6.69,9.77)	7.88(6.69,9.93)	8.04(6.73,9.54)	-0.538	0.590
RBC,10^{12}/L, (mean ± SD)	3.84 ± 0.68	3.91 ± 0.65	3.62 ± 0.71	2.969	0.003
HGB, g/L (mean ± SD)	117.37 ± 20.26	119.83 ± 18.90	109.72 ± 22.49	3.377	0.001
HCT,% ,(mean ± SD)	35.72 ± 5.94	36.51 ± 5.54	33.28 ± 6.48	3.706	< 0.001
PLT,10^9/L, (mean ± SD)	178.64 ± 86.71	178.18 ± 91.41	180.05 ± 70.87	-0.162	0.872
NEUT,10^9 /L(mean ± SD)	6.87 ± 3.17	7.02 ± 3.25	6.41 ± 2.86	1.283	0.201
LYM,10^9/L(mean ± SD)	1.07(0.81,1.41)	1.05(0.80,1.41)	1.09(0.83,1.46)	0.629	0.529
MPV, fL(mean ± SD)	10.51 ± 1.65	10.55 ± 1.71	10.37 ± 1.42	0.737	0.462
PDW, fL(mean ± SD)	16.18 ± 0.92	16.18 ± 1.04	16.20 ± 0.35	-0.202	0.840
CRP, mg/L(mean ± SD)	20.15(7.79,54.72)	19.78(8.19,53.91)	24.15(6.65,59.22)	0.251	0.802
D-Dimer, ug/L, (mean ± SD)	2555(769,4715)	2086(697,4640)	2948(1525,4756)	1.714	0.086
PT, s(mean ± SD)	12.00 ± 1.07	12.07 ± 1.08	11.80 ± 1.02	1.662	0.098
aPTT, s(mean ± SD)	29.43 ± 3.38	29.79 ± 3.36	28.32 ± 3.23	2.938	0.004
TT, s(mean ± SD)	14.73 ± 1.76	14.65 ± 1.63	14.99 ± 2.10	-1.127	0.263
FIB, g/L(mean ± SD)	3.46 ± 0.94	3.44 ± 0.94	3.53 ± 0.95	-0.588	0.557
TP, s(mean ± SD)	62.99 ± 6.39	63.58 ± 6.44	61.18 ± 5.94	2.509	0.013
ALB, g/L(mean ± SD)	37.27 ± 4.85	37.75 ± 4.86	35.78 ± 4.54	2.737	0.007
Thrombosis risk score					
Caprini scores(mean ± SD)	3.71 ± 2.03	3.18 ± 1.69	5.38 ± 2.08	-7.306	< 0.001

Abbreviations: standard deviation, SD; interquartile range, IQR; white blood cell count, WBC; red blood cell count, RBC; haemoglobin, HGB; haematocrit, HCT; platelet count, PLT; neutrophil count, NEUT; lymphocyte count, LYM; mean platelet volume, MPV; platelet distribution width, PDW; C-reactive protein, CRP; high-sensitivity D-dimer, D-D; prothrombin time, PT; activated partial thromboplastin time, aPTT; thrombin time, TT; fibrinogen, FIB; total protein level, TP; albumin level, ALB.SD, standard deviation; IQR, interquartile range

Table 2 Results of the multivariate logistic regression model for DVT in patients with hip fractures at admission

Variables	β	S.E	Wald χ^2	*P*	OR(95%CI)
Sex (Female vs. Male)	1.012	0.414	5.973	0.015	2.752(1.222,6.196)
Cardiac arrhythmia (Yes vs. No)	1.560	0.546	8.162	0.004	4.757(1.632,13.869)
Intertrochanteric fracture (Yes vs. No)	1.144	0.418	7.486	0.006	3.138(1.383,7.120)
Time from injury to admission (≥48 h vs.<48 h)	1.095	0.463	5.592	0.018	2.989(1.206,7.407)
aPTT	-0.196	0.067	8.605	0.003	0.822(0.721,0.937)
Caprini scores	0.585	0.101	33.651	<0.001	1.796(1.473,2.188)

Table 3 Stratification results for DVT at admission using the model

Model probability	Risk Stratification	Total	Non-DVT group($n=180$)	DVT group($n=58$)	χ^2	*P*
< 0.2	Low Risk	144(60.50)	133(92.36)	11(7.64)	78.942	< 0.001
0.2 ~ 0.6	Moderate Risk	63(26.47)	41(65.08)	22(34.92)		
> 0.6	High Risk	31(13.03)	6(19.35)	25(80.65)		

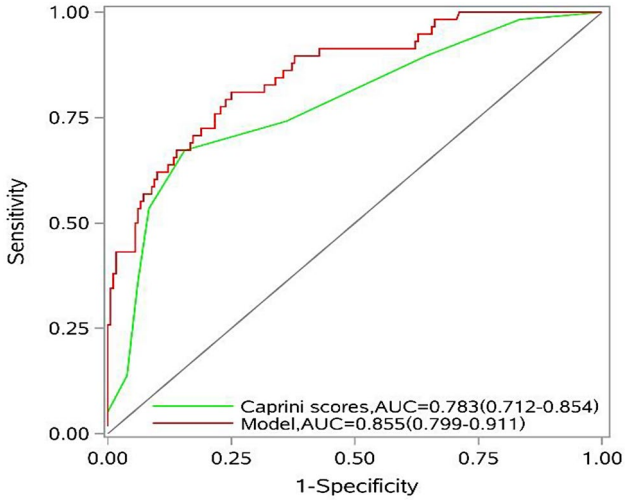

Fig. 2 ROC curves for Caprini scores and model in diagnosing thrombosis in patients

Table 4 Comparison of diagnostic efficacy for DVT at admission: Caprini scores vs. model

Index	Value	95% CI	*P*
Difference in AUC	0.072	0.028 ~ 0.117	0.001
IDI	0.131	0.074 ~ 0.187	< 0.001
NRI	0.814	0.544 ~ 1.084	< 0.001

remark: [a]Model vs. Caprini scores

clinical work, clinicians should prioritize educating female patients with hip fracture, and active intervention measures should be taken to reduce the incidence of DVT.

In this study, cardiac arrhythmias were associated with DVT at admission in patients with hip fracture. The risk of DVT in the DVT group was 4.757 times that in the non-DVT group. Previous studies have shown that coronary heart disease is an independent risk factor for preoperative DVT in patients with hip fractur [5, 17]. The results of this study are different from those of previous studies. This may be related to the differences in the population, outcome variables, and sample sizes between our study and other studies. Hip fracture patients complicated with cardiac arrhythmias should be considered at high risk of thrombus.This study indicates that patients with intertrochanteric fractures have a higher risk of developing deep vein thrombosis (DVT) compared to those with other types of hip fractures. These findings are consistent with previous studies [11]. The elevated risk may be attributed to the fact that patients with intertrochanteric fractures are often elderly, with severe osteoporosis and functional impairments, which significantly increase the likelihood of adverse outcomes. Therefore, special attention should be given to the prevention and

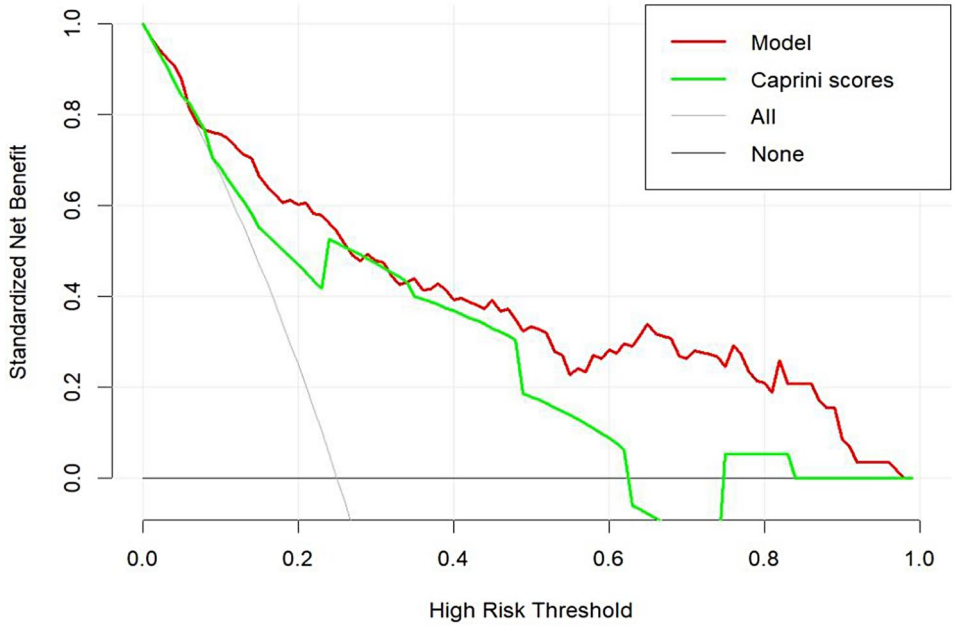

Fig. 3 DCA curves for Caprini scores and model in diagnosing thrombosis in patients with hip fractures

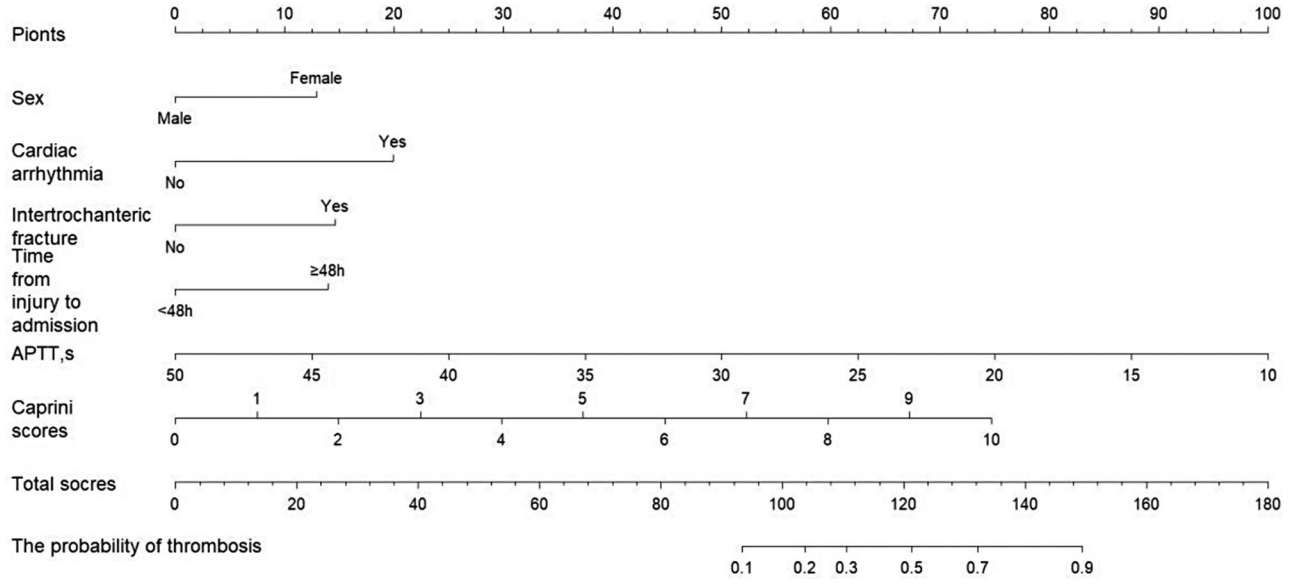

Fig. 4 Nomogram model for DVT in patients with hip fractures using the model

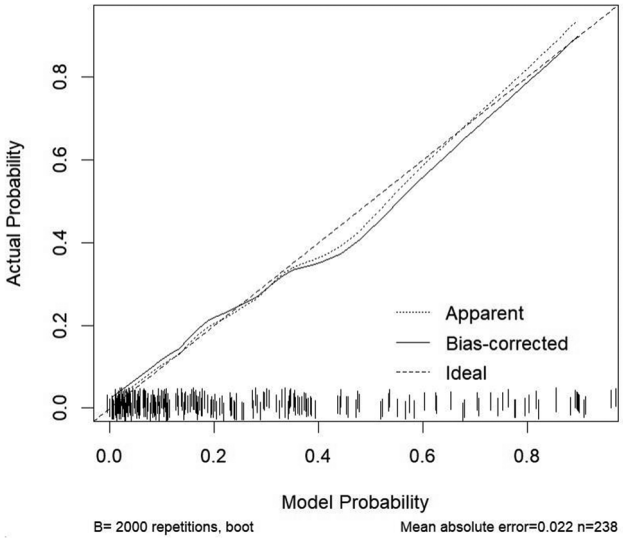

Fig. 5 Calibration curve for the DVT model in patients with hip fractures

management of DVT in patients with intertrochanteric fractures in clinical practice.

Most studies have shown that the time from fracture to admission (delayed admission) is closely related to the development of DVT of the lower extremities in patients with hip fracture. A previous study showed that for every 1 day of delay in hospitalization of elderly patients with intertrochanteric fracture, the risk of DVT increased by 37% [13]. In this study, the time from fracture to admission was associated with the development of lower extremity venous thrombosis in patients with hip fracture at admission. When the duration from fracture to admission was ≥48 h, the risk of thrombosis increased. Previous studies have shown that the time from fracture to admission is an independent risk factor for the development of DVT of the lower extremities in patients with hip fracture [1, 8, 13, 18–21].According to Bengoa et al. [22] there is a high prevalence of DVT among elderly hip fracture patients with delayed hospitalization. The results of the present study were consistent with those of previous studies. An analysis of the causes showed that after a patient fractured a hip, venous congestion, vascular injury and immobilization, as well as patient condition, family care, and medical conditions, affected the timely admission of the patient to the hospital, which promoted thrombus formation. Therefore, clinicians should focus on patients at risk of hip fracture and ask them to take timely measures to reduce the incidence of fractures. Patients after hip fracture should be encouraged to seek medical treatment in a timely manner to reduce the risk of DVT of the lower extremities.

aPTT is closely related to lower extremity DVT in patients with hip fracture at admission. In this study, a shorter aPTT was associated with an increased risk of DVT of the lower extremities in patients with hip fracture. According to Zhao, Weiguang et al., aPTT is a risk factor for the formation of solitary DVT in the calf of patients with hip fracture before surgery. Therefore, the results of the present study are consistent with those of previous studies. The reason may be that hip fracture patients with short aPTTs may develop thrombi through the intrinsic coagulation pathway [12], Fracture may cause vascular injury, which may activate the coagulation system [18].Thrombus formation is a dynamic process, and these unique properties of blood are determined to a large extent by the complex and active balance among procoagulant factors, anticoagulants and fibrinolysis.

This pathological condition is usually associated with imbalances in this intricate system, eventually leading to the formation of intravascular thrombi [23].Therefore, in clinical work, special attention should be paid to changes in the aPTT value in patients with hip fracture. When this value is lower than the normal value, the high risk of thrombus formation in patients with hip fracture should be evaluated, and anticoagulant therapy should be strictly monitored.

The Caprini score is a commonly used tool for assessing the risk of deep vein thrombosis (DVT) in patients with hip fractures. This study found that the Caprini score is associated with the occurrence of DVT in hip fracture patients. However, the diagnostic model developed in this study outperformed the Caprini score. The model demonstrated an improvement in the area under the curve (AUC) by 0.072 (Difference in AUC = 0.072, 95% CI = 0.028–0.117). The model's ability to diagnose DVT increased by 13.1% (IDI = 0.131, 95% CI = 0.074–0.187), and the likelihood of correctly identifying DVT improved by 81.4% (NRI = 0.814, 95% CI = 0.544–1.084), with $P < 0.05$. Decision curve analysis (DCA) showed that the model's standardized net benefit was higher than that of the Caprini score at threshold probabilities of 0.1–0.22 and 0.35–1.00.Compared with the Caprini score, the risk factors included in the diagnostic model were derived specifically from this population, making it more tailored and specific for hip fracture patients. Furthermore, the nomogram model is well-defined, simple, intuitive, visual, and easy to apply in clinical practice.

Although this study did not identify a significant association between age and the occurrence of deep vein thrombosis (DVT) in patients with hip fractures, age remains an important factor in the Caprini score. Moreover, previous studies have demonstrated a strong correlation between advanced age and the risk of DVT in hip fracture patients [6, 19, 24–27], a meta-analysis showed that advanced age is an independent risk factor for the development of DVT of the lower extremity in patients with hip fracture [5].An acquired prothrombotic state, anatomical changes in the inferior veins, and thickening of the venous valve cusp were determined to be potential causes [28].Therefore, in clinical practice, it is essential to remain vigilant about the occurrence of DVT in elderly patients.

This study still has several limitations. First, as a single-center retrospective study, the model developed in this research was only evaluated through internal validation. Future studies should include multi-center, large-sample prospective research to further validate the findings. Second, the observation period of this study was relatively short, focusing primarily on the first 24 h after admission for patients with hip fractures. No analysis was conducted on the occurrence of deep vein thrombosis (DVT) beyond the initial 24 h.In the future, dynamic assessments and analyses of this complication throughout the entire course of hospitalization, from admission to discharge, could provide a more comprehensive understanding of the role and impact of DVT in the progression of hip fracture. Additionally, incorporating other potential risk factors and external validation of the model could further enhance its clinical applicability and reliability.

Conclusion

This study developed a nomogram diagnostic model for deep vein thrombosis (DVT) in hip fracture patients, which demonstrated superior performance compared to the traditional Caprini score. Multivariate logistic regression identified female gender, cardiac arrhythmia, intertrochanteric fractures, fracture duration before admission (≥ 48 h), aPTT, and Caprini scores as significant risk factors for DVT. The model achieved an AUC of 0.855 (bias-corrected C-index: 0.836) and showed improvements in IDI (0.131) and NRI (0.814), with good calibration and discrimination. Decision curve analysis confirmed its clinical utility at various threshold probabilities. Delayed admission (≥ 48 h) and intertrochanteric fractures were strongly associated with increased DVT risk, consistent with previous studies. The nomogram provides a simple, visual tool for early DVT risk assessment, enabling timely intervention and improved patient outcomes. However, further multi-center prospective studies are needed to validate its generalizability.

Abbreviations

Acc	accuracy
ALB	albumin level
AUC	areas under the ROC curve
aPTT	activated partial thromboplastin time
CI	confidence interval
C-index	concordance index
CRP	C-reactive protein
DCA	decision curve analysis
D-D	high-sensitivity D-dimer
DVT	deep vein thrombosis
FIB	fibrinogen
HCT	haematocrit
HGB	counthaemoglobin
IQR	interquartile range
IDI	integrated discrimination improvement index
LYM	lymphocyte count
MPV	mean platelet volume
NEUT	neutrophil count
NRI	net reclassification improvement
OR	odds ratio
PDW	platelet distribution width
PLT	platelet count
PT	prothrombin time
RBC	red blood cell
ROC	receiver operator characteristic curve
Sen	sensitivity
Spe	specificity
SD	standard deviation
TP	total protein level
TT	thrombin time
WBC	white blood cell count

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Author contributions
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Data availability
The datasets used and analysed during the current study are not publicly available due to the authors do not have permission to share data, but are available from the corresponding author on reasonable request.

Declarations

Ethical approval
This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013.This study was approved by the institutional review board (IRB) of the Third Affiliated Hospital of Chongqing Medical University (No. 2024057).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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