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Construction of a nomogram for preoperative deep vein thrombosis in pelvic fracture patients

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Abstract

Background In recent years, the incidence of pelvic fractures has been on the rise, predominantly affecting the elderly population. Deep vein thrombosis may lead to poor prognosis in patients. monocyte-to-lymphocyte ratio is novel biomarkers of inflammation, and this study aims to verify their predictive effect and construct the nomogram model.

Method This study used binary logistic regression analysis to predict the predictive effect of MLR on the occurrence of DVT in pelvic fractures patients. And use R studio to construct nomogram model.

Result The results showed that Age (1.04 [1.01, 1.07], $p=0.006$), WBC (1.44 [1.28, 1.61], $p<0.001$), and MLR (2.11 [1.08, 4.13], $p=0.029$) were independent predictive factors. The nomogram demonstrated good predictive performance with small errors in both the training and validation groups, and most clinical patients could benefit from them.

Conclusion The nomogram constructed based on MLR can assist clinicians in early assessment of the probability of DVT occurrence.

Keywords Pelvic fractures, Deep vein thrombosis, Monocyte to lymphocyte ratio, Nomogram

Background

In recent years, the incidence of pelvic fractures has been on the rise, predominantly affecting the elderly population. These fractures are mainly caused by trauma and account for approximately 1.5-3% of all skeletal injuries, with an increase of about 2.4 times in the past 30 years. The one-year mortality rate associated with these fractures ranges from 14 to 25% [1]. The severity of fractures varies from avulsion of the bone epiphysis to complete rupture of the pelvic ring. Previous studies have shown that up to 30% of pelvic fractures are not initially detected on X-rays [2]. In unstable fractures treated conservatively, the prognosis is usually poor, often requiring adequate reduction and surgical stabilization to avoid long-term complications [3, 4]. Pelvic fractures are often accompanied by various complications, including pelvic bleeding, urethral injury, infection, multiple systemic injuries, deep vein thrombosis, and death [5–8]. Pelvic fractures have become a significant public health issue and a socioeconomic burden [9].

Deep vein thrombosis (DVT) is common in trauma patients [10], and studies have shown that the incidence of DVT is higher in pelvic fractures compared to other types of fractures [11]. A study in Taiwan found that the

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overall incidence of DVT and symptomatic pulmonary embolism in patients with pelvic and acetabular fractures was 3.48%, with 46.1% of patients being asymptomatic [5]. Many scholars have pointed out that early screening for DVT should be conducted in patients with pelvic fractures to achieve early prevention [12]. Therefore, we need more intuitive, simpler, and easily obtainable predictive indicators in the early stages of the disease to meet the goals of early prevention and treatment in clinical practice.

In recent years, the predictive role of inflammatory factors in the occurrence of DVT in fracture patients has received much attention [13]. Melinte Răzvan Marian et al. [14] found that preoperative systemic immune-inflammatory factors and other inflammatory factors can effectively predict the formation of deep vein thrombosis in patients after total knee arthroplasty. Zhang Liang et al. [15] constructed a nomogram based on systemic immune-inflammatory factors to predict the occurrence of preoperative DVT in elderly patients with hip fractures. Gao Zhida et al. [16] suggested that the neutrophil-to-lymphocyte ratio can predict the occurrence of preoperative DVT in patients with ankle fractures. Melinte RM et al. [17] believe that preoperative MLR strongly predicts the occurrence of acute DVT in patients after total knee arthroplasty. However, there have been no studies on the development of a nomogram for the occurrence of deep vein thrombosis in patients with pelvic fractures using the monocyte-to-lymphocyte ratio (MLR) as a novel inflammatory factor.

Therefore, the aim of this study is to collect the results of routine blood tests and biochemical examinations upon patient admission, and to develop a nomogram for the prediction of preoperative deep vein thrombosis in patients with pelvic fractures based on the MLR. This nomogram aims to provide a non-invasive, early, and simple prediction tool to assist clinicians in making early decisions.

Materials and methods

Patient section

This is a retrospective study. A total of patients diagnosed with pelvic fractures from January 2015 to January 2023 at the First Affiliated Hospital of Guangxi Medical University hospital were included in this study. The inclusion criteria were as follows: patients diagnosed with pelvic fractures based on the following criteria: (a) Clear history of trauma; (b) Clinical manifestations including widespread pain, exacerbation of pain in the lower limbs or when sitting, local tenderness, congestion, rotation of the lower limbs, and deformity; (c) Imaging examinations (X-ray and CT) indicating pelvic fractures; (d) Non critical patients; (e) Age > 18 years. The exclusion criteria were as follows: (1) Inability to obtain hematological examination and vascular color Doppler ultrasound results; (2) Recent use of anticoagulants or antiplatelet drugs; (3) Concomitant immune system and hematological disorders; (4) Patients with critical illness and short-term death; (5) Patients with infectious diseases and acute or chronic infections.

According to the US Critical Care Guidelines [18], all patients included will be treated with low-molecular-weight heparin as early as possible (within 24 h) after injury to prevent thrombosis, combined with mechanical prophylaxis. This regimen will be used as a routine for all patients.

As this is a retrospective study, the ethics committee approved the study without requiring patients to sign informed consent forms, in accordance with national laws and institutional agreements. In this study, patients' personal identifying information will be anonymized.

Data collection and definition

This study collected baseline clinical data and laboratory test results including complete blood count, blood biochemistry, and coagulation function. The baseline clinical data included gender, age, affected side, history of hypertension, history of diabetes, history of heart disease, history of hepatitis, history of alcohol consumption, and smoking history.

Additionally, the study collected the following laboratory data upon patient admission White blood cell count (WBC), Red blood cell count (RBC), Hemoglobin (HGB), Mean corpuscular hemoglobin concentration (MCHC), Mean corpuscular volume (MCV), Neutrophils (NC), Lymphocyte (LYM), Monocyte (MONO), Eosinophils (Eos), Basophil (Baso), Albumin (ALB), Aspartate aminotransferase (AST), Alanine aminotransferase (ALT), Total bilirubin (TBIL), Creatinine (Cr), Blood urea nitrogen (BUN), Prothrombin time (PT), Activated partial thromboplastin time (APTT), Fibrinogen (FIB), and other relevant data. Among these, the inflammatory factor validated in this study is monocyte-to-lymphocyte ratio (MLR) = monocyte /lymphocyte.
All of our patients have completed the collection of blood routine tests and related testing items in the emergency department or at the time of admission.

Outcome

All patients were diagnosed through lower limb venous color Doppler ultrasound examination. Color Doppler ultrasound examination has high sensitivity and accuracy, and is widely used in clinical practice, making it the preferred method for DVT diagnosis [19]. In this study, the occurrence of DVT before surgery in patients with pelvic fractures was considered as the outcome event, The presence of DVT was defined as a positive result, while the absence of DVT was defined as a negative result. All patients were diagnosed with deep vein thrombosis for the first time.

Statistical methods

In this study, the data was first randomly divided into a training group and a validation group in a 7:3 ratio using SPSS 21.0 (SPSS Inc., Chicago, IL). Then, a comparison of baseline data between the training group and the validation group was conducted to verify their comparability.

Next, the training group data was divided into groups based on the presence or absence of DVT, and comparisons were made between the clinical data and laboratory test results. For continuous data, the Shapiro-Wilk test was used to determine normality. If the data followed a normal distribution, it was presented as mean ± standard deviation, and one-way analysis of variance (ANOVA) was used for group comparisons. If the data did not follow a normal distribution, it was presented as median (25th percentile, 75th percentile), and the Kruskal-Wallis test was used for group comparisons.

Categorical data were described using frequencies (percentages), and group comparisons were performed using the chi-square test or Fisher's exact test. A *p*-value less than 0.05 was considered statistically significant for two-sided tests.

To calculate the optimal cutoff value, sensitivity, specificity, and other results for factors with statistically significant differences in the inter-group comparison of the training group using SPSS 21.0 software. Additionally, use GraphPad Prism 9.5.0 to plot the receiver operating characteristic (ROC) curve for the differentiating factors.

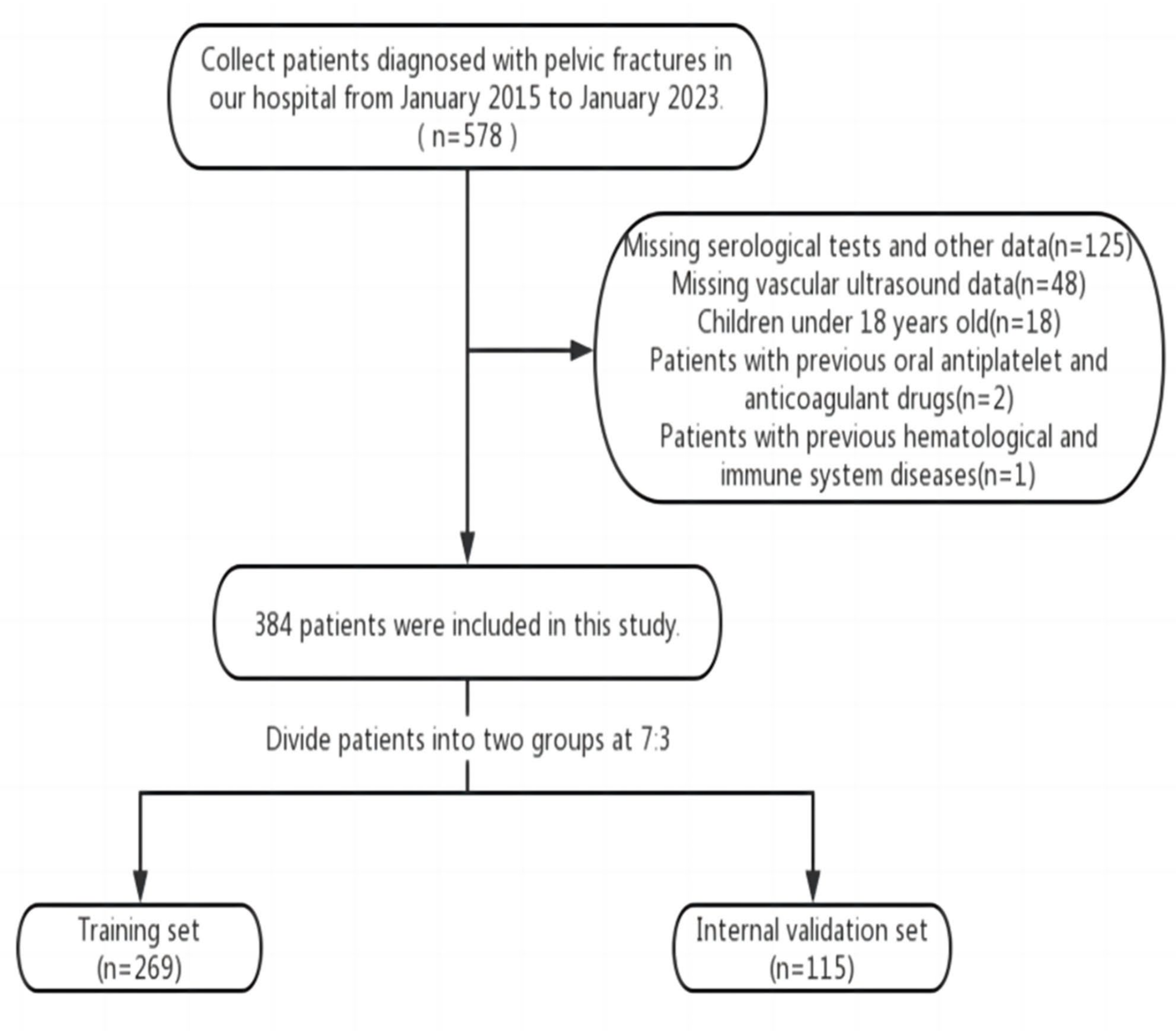

Fig. 1 Flow chart of this study

Table 1 Baseline data table for comparison of training test and validation test

Variable	training test (*n* = 269)	validation test (*n* = 115)	Sum (*N* = 384)	*p*
Sex				0.590
Male	144 (53.53%)	65 (56.52%)	209 (54.43%)	
Female	125 (46.47%)	50 (43.48%)	175 (45.57%)	
Age(years)	46 (34,57)	48 (31.5,61)	47 (33,58)	0.526
Hypertension				0.906
No	242 (89.96%)	103 (89.57%)	345 (89.84%)	
Yes	27 (10.04%)	12 (10.43%)	39 (10.16%)	
Diabetes				0.066
No	254 (94.42%)	114 (99.13%)	368 (95.83%)	
Yes	15 (5.58%)	1 (0.87%)	16 (4.17%)	
Heart disease				1.000
No	265 (98.51%)	114 (99.13%)	379 (98.7%)	
Yes	4 (1.49%)	1 (0.87%)	5 (1.3%)	
Smoke				0.393
No	203 (75.46%)	82 (71.3%)	285 (74.22%)	
Yes	66 (24.54%)	33 (28.7%)	99 (25.78%)	
Alcoholism				0.326
No	209 (77.7%)	84 (73.04%)	293 (76.3%)	
Yes	60 (22.3%)	31 (26.96%)	91 (23.7%)	
Hepatitis				0.379
No	261 (97.03%)	114 (99.13%)	375 (97.66%)	
Yes	8 (2.97%)	1 (0.87%)	9 (2.34%)	

We use the optimal cutoff value as the threshold to classify the clinical factors. We included all variables in the univariate binary logistic regression analysis, and then included single factors with $P<0.05$ in the multivariate binary logistic regression analysis to obtain independent predictors($P<0.05$). All variables we included are binary variables.

Based on the results of the multivariable binary logistic regression, use R Studio (version 4.2.2) to draw a nomogram for the independent predictive factors in the training group. Evaluate the predictive performance of the model using the ROC curve and the area under the curve (AUC). Calculate the average error of the model using a calibration plot. Analyze the clinical benefits of the model using a decision curve analysis (DCA) plot. Additionally, perform relevant analyses and plot graphs for the validation group to validate the effectiveness of the model.

Result

A total of 578 patients with pelvic fractures were collected for this study. Among them, 194 patients were excluded due to the aforementioned factors, and a total of 384 patients were included in the retrospective study, as shown in Fig. 1. The training group consisted of 269 patients, and the validation group consisted of 115 patients.

Baseline data for the two groups were compared. There are 125 and 50 females (46.47%, 43.48%) in the training and validation groups, respectively, with median ages of 46 years (34,57) and 48 years (31.5,61). The number of patients with hypertension, diabetes, heart disease, smoking, drinking and hepatitis history was 27 and 12 (10.04%, 10.43%), 15 and 1 (5.58%, 0.87%), 4 and 1 (1.49%, 0.87%), 66 and 33 (24.54%, 28.7%), 60 and 31 (22.3%, 28.3%), 8 and 1 (2.97%, 0.87%), respectively. There were no statistically significant differences in baseline data between the two groups ($p>0.05$), indicating comparability of the data (Table 1).

The training group data was divided into two groups based on the presence or absence of DVT. The group with DVT was defined as the DVT group, and the group without DVT was defined as the No DVT group. A comparison was made between the two groups, and the results showed that RBC, HGB, MCV, WBC, NC, MLR, LYM, MONO, and albumin had statistically significant differences among the different groups of DVT ($p<0.05$) (Table 2). Box plots were created for the factors with significant differences to facilitate visual comparison (Fig. 2). The optimal cutoff values, sensitivity, and specificity were calculated for each differentiating factor (Table 3). ROC curves were plotted, and the area under the curve (AUC) was calculated (Fig. 3). The results showed that the optimal cutoff value for RBC was 3.505*1012/L, with a sensitivity of 0.621 and specificity of 0.652. For HGB, the optimal cutoff value was 105.8 g/L, with a sensitivity of 0.672 and specificity of 0.571. The optimal cutoff value for MCV was 88.675fL, with a sensitivity of 0.638 and specificity of 0.586. The optimal cutoff value for WBC was 10.625*109/L, with a sensitivity of 0.793 and specificity of 0.753. The optimal cutoff value for NC was 8.515*109/L, with a sensitivity of 0.793 and specificity of 0.758. The optimal cutoff value for MLR was 0.506, with a sensitivity of 0.759 and specificity of 0.591.

Including various clinical factors in a univariate binary logistic regression analysis, the results showed that Age (1.79 [1.01, 3.19], $p=0.047$), RBC (0.33 [0.18, 0.6], $p<0.001$), HGB (0.37 [0.2, 0.68], $p=0.001$), MCV (2.49 [1.36, 4.57], $p=0.003$), WBC (11.66 [5.72, 23.77], $p<0.001$), NC (11.98 [5.87, 24.45], $p<0.001$), MLR (4.54 [2.34, 8.83], $p<0.001$), LYM (0.31 [0.17, 0.57], $p<0.001$), MONO (3.26 [1.78, 5.96], $p<0.001$), ALB (0.41 [0.21, 0.8], $p=0.009$), AST (2.38 [1.08, 5.21], $p=0.031$), and Cr (0.5 [0.26, 0.95], $p=0.035$) were all risk factors for DVT (Table 4).

When significant factors from the univariate analysis were included in a multivariate binary logistic regression analysis, the results showed that Age (1.04 [1.01, 1.07], $p=0.006$), WBC (1.44 [1.28, 1.61], $p<0.001$), and MLR (2.11 [1.08, 4.13], $p=0.029$) were independent predictive factors (Table 5).

In order to further validate the predictive ability of various factors for patients with pelvic fractures,

Table 2 Comparison of clinical factors between the DVT group and the No DVT group

Variable	No DVT (*n* = 208)	DVT (*n* = 61)	Sum (*N* = 269)	*p*
Sex				0.286
Male	115 (55.29%)	29 (47.54%)	144 (53.53%)	
Female	93 (44.71%)	32 (52.46%)	125 (46.47%)	
Age	45 (34,55)	51 (34,61)	46 (34,57)	0.093
Hypertension				0.671
No	188 (90.38%)	54 (88.52%)	242 (89.96%)	
Yes	20 (9.62%)	7 (11.48%)	27 (10.04%)	
Diabetes				0.95
No	197 (94.71%)	57 (93.44%)	254 (94.42%)	
Yes	11 (5.29%)	4 (6.56%)	15 (5.58%)	
Heart disease				1
No	205 (98.56%)	60 (98.36%)	265 (98.51%)	
Yes	3 (1.44%)	1 (1.64%)	4 (1.49%)	
Smoke				0.093
No	152 (73.08%)	51 (83.61%)	203 (75.46%)	
Yes	56 (26.92%)	10 (16.39%)	66 (24.54%)	
Alcoholism				0.362
No	159 (76.44%)	50 (81.97%)	209 (77.7%)	
Yes	49 (23.56%)	11 (18.03%)	60 (22.3%)	
Hepatitis				0.788
No	201 (96.63%)	60 (98.36%)	261 (97.03%)	
Yes	7 (3.37%)	1 (1.64%)	8 (2.97%)	
RBC(*10^{12}/L)	3.86 (3.22,4.56)	3.36 (2.86,4.04)	3.73 (3.04,4.46)	0.002
HGB(g/L)	108.17 ± 25.04	98.41 ± 25.09	105.96 ± 25.33	0.01
MCV(fL)	87.12 (83.07,91.04)	90.18 (84.65,92.23)	87.75 (83.46,91.31)	0.02
MCHC(g/L)	329.6 (321.32,336.28)	328.1 (322.48,335.15)	328.95 (321.78,336)	0.657
WBC(*10^9/L)	8.55 (6.67,10.58)	14.8 (10.72,17.8)	9.15 (7.11,12.11)	< 0.001
NC(*10^9/L)	6.18 (4.24,8.5)	12.64 (8.88,15.37)	7.35 (4.68,10.3)	< 0.001
MLR	0.45 (0.26,0.67)	0.66 (0.51,1.16)	0.49 (0.28,0.79)	< 0.001
LYM(*10^9/L)	1.27 (0.88,1.92)	0.96 (0.68,1.46)	1.22 (0.81,1.82)	0.002
MONO(*10^9/L)	0.54 (0.41,0.73)	0.72 (0.48,1.23)	0.57 (0.42,0.78)	< 0.001
Eos(*10^9/L)	0.1 (0.01,0.18)	0.08 (0.01,0.18)	0.08 (0.01,0.18)	0.6
Baso(*10^9/L)	0.02 (0.01,0.04)	0.02 (0.01,0.03)	0.02 (0.01,0.04)	0.489
PT(s)	11.8 (10.9,12.7)	11.85 (11.15,13)	11.8 (10.9,12.78)	0.446
APTT(s)	30 (27.8,32.88)	30.05 (28.12,33.42)	30 (27.9,33.32)	0.502
FIB(g/L)	4.04 (3.1,5.01)	4.44 (3.2,5.34)	4.06 (3.11,5.04)	0.254
ALB(g/L)	36.62 ± 6.18	34.42 ± 5.7	36.15 ± 6.14	0.026
GGT(U/L)	25.5 (17,47)	23 (15,38)	24 (17,43)	0.408
ALT(U/L)	29 (15,48)	28 (21,49)	29 (15.5,48.5)	0.735
AST(U/L)	29.5 (19,57)	36 (25,54)	31 (19.5,57)	0.175
TBIL(umol/L)	12.3 (7.8,18.2)	14.7 (9.5,21.7)	12.55 (8.5,18.38)	0.138
Cr(umol/L)	59 (47,72.25)	53 (43.5,66)	58 (46,71.5)	0.209
BUN(mmol/L)	4.9 (3.86,6.39)	4.8 (3.55,6.31)	4.89 (3.77,6.4)	0.454

Note: WBC: White blood cell count; RBC: Red blood cell count; HGB: Hemoglobin; MCV: Mean corpuscular volume; MCHC: Mean corpuscular hemoglobin concentration; NC: Neutrophils; LYM: Lymphocyte; MONO: Monocyte; Eos: Eosinophils; Baso: Basophil; ALB: Albumin; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; TBIL: Total bilirubin; PT: Prothrombin time; APTT: Activated partial thrombin time; FIB: Fibrinogen; Cr: Creatinine; BUN: Blood urea nitrogen; MLR: Monocyte to lymphocyte ratio

a nomogram model was constructed using R studio software based on the results of the multivariate analysis (Age, WBC, MLR). The column line chart was constructed using the data from the training group, as shown in Fig. 4. The training group ROC curve was plotted to validate the predictive performance of the column line chart (Fig. 5A), with a C-index of 0.845, indicating good predictive performance. The training group calibration curve was plotted (Fig. 6A), which showed a mean error of 0.02. The training group decision curve analysis (DCA)

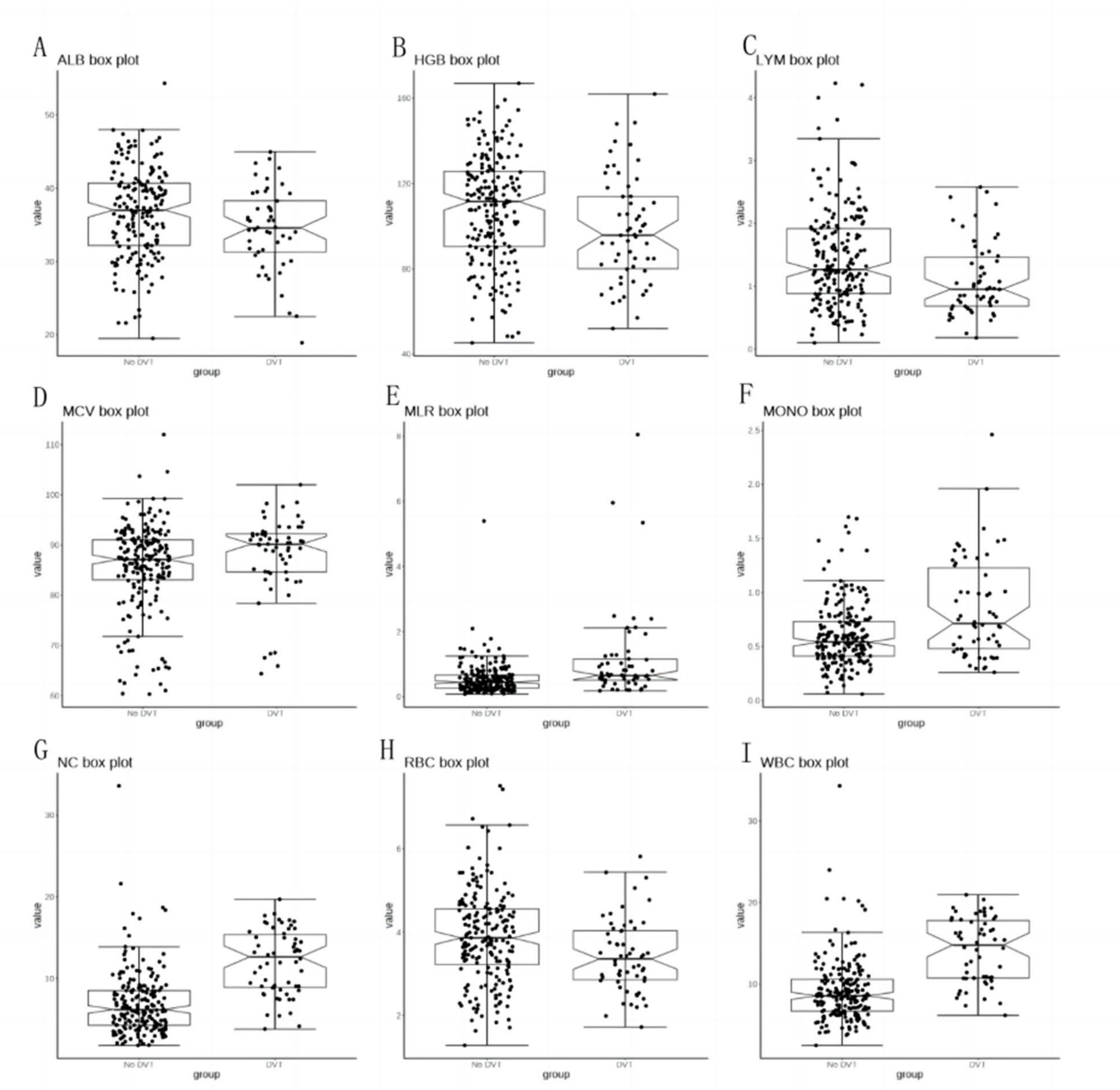

Fig. 2 Box plot of clinical differential factors

was plotted (Fig. 7A), indicating good clinical benefit within the threshold range of 0.01–0.99.

The validation group data was also used for validation. The ROC curve was plotted (Fig. 5B), with a C-index of

Table 3 The area under the ROC curve and its cutoff value for clinical factors with statistical differences

Variable	AUC	AUC[95%CI]	*p*	Cutoff value	Sensitivity	specificity
RBC(*10^{12}/L)	0.635	[0.557,0.713]	0.002	3.505	0.621	0.652
HGB(g/L)	0.622	[0.54,0.704]	0.005	105.8	0.672	0.571
MCV(fL)	0.601	[0.517,0.685]	0.020	88.675	0.638	0.586
WBC(*10^9/L)	0.829	[0.77,0.888]	0.000	10.625	0.793	0.753
NC(*10^9/L)	0.836	[0.777,0.895]	0.000	8.515	0.793	0.758
MLR	0.696	[0.616,0.776]	0.000	0.506	0.759	0.591

Note: WBC: White blood cell count; RBC: Red blood cell count; HGB: Hemoglobin; MCV: Mean corpuscular volume; NC: Neutrophils; MLR: Monocyte to lymphocyte ratio

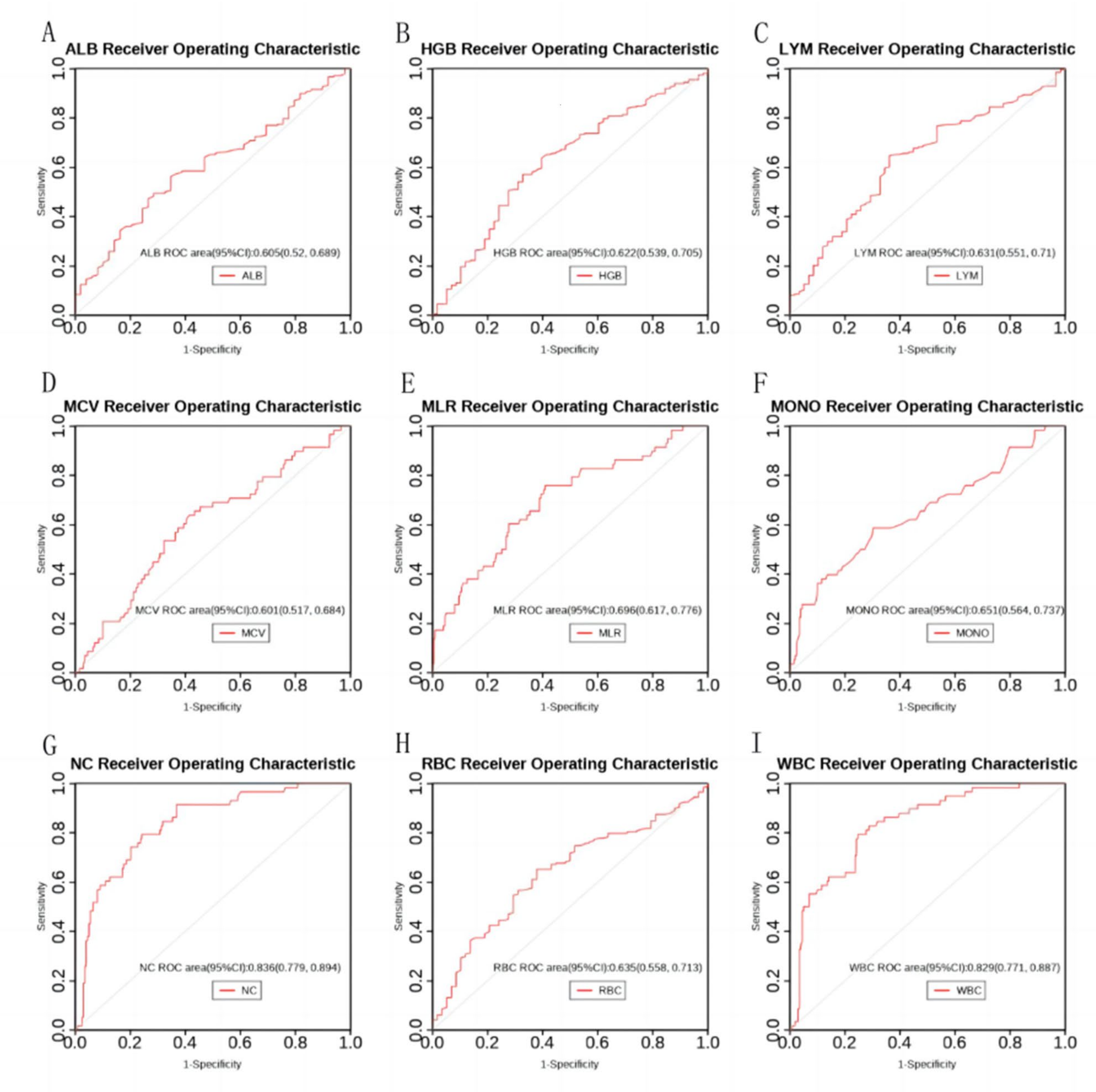

Fig. 3 Receiver operating characteristic of clinical differential factors

0.876. The calibration curve was plotted (Fig. 6B), showing a mean error of 0.032. The DCA was plotted (Fig. 7B), indicating good clinical benefit within the threshold range of 0.01–0.99.

It can be seen that the nomogram exhibited good predictive performance with small errors in both the training and validation groups, and it can benefit the majority of clinical patients.

Discussion

It is common for patients with fractures to develop deep vein thrombosis (DVT), and many scholars believe that DVT should be detected, prevented, and treated early [20–23]. Color Doppler ultrasound is considered the gold standard for diagnosing DVT and is often recommended to be performed early in the course of the disease [24]. However, in clinical practice, we have found that color Doppler ultrasound examinations can often result in significant errors due to difficulties in cooperation from patients with pelvic fractures and lower limb swelling,

Table 4 Single factor binary logistic regression analysis results

Variable	B	SE	z	*p*	OR[95%CI]
Sex					
Male					1
Female	0.311	0.292	1.065	0.287	1.36[0.77,2.42]
Age(years)					
≤ 50.5					1
> 50.5	0.585	0.294	1.991	0.047	1.79[1.01,3.19]
Hypertension					
No					1
Yes	0.198	0.466	0.425	0.671	1.22[0.49,3.03]
Diabetes					
No					1
Yes	0.229	0.603	0.379	0.705	1.26[0.39,4.1]
Heart disease					
No					1
Yes	0.13	1.164	0.112	0.911	1.14[0.12,11.15]
Smoke					
No					1
Yes	-0.631	0.380	-1.662	0.097	0.53[0.25,1.12]
Alcoholism					
No					1
Yes	-0.337	0.371	-0.909	0.364	0.71[0.35,1.48]
Hepatitis					
No					1
Yes	-0.737	1.079	-0.683	0.495	0.48[0.06,3.97]
RBC(*10^{12}/L)					
≤ 3.505					1
> 3.505	-1.118	0.309	-3.619	< 0.001	0.33[0.18,0.6]
HGB(g/L)					
≤ 105.8					1
> 105.8	-1.004	0.314	-3.192	0.001	0.37[0.2,0.68]
MCV(fL)					
≤ 88.675					1
> 88.675	0.913	0.309	2.956	0.003	2.49[1.36,4.57]
MCHC(g/L)					
≤ 329.05					1
> 329.05	-0.409	0.302	-1.353	0.176	0.66[0.37,1.2]
WBC(*10^9/L)					
≤ 10.625					1
> 10.625	2.456	0.364	6.755	< 0.001	11.66[5.72,23.77]
NC(*10^9/L)					
≤ 8.515					1
> 8.515	2.483	0.364	6.820	< 0.001	11.98[5.87,24.45]
MLR					
≤ 0.506					1
> 0.506	1.513	0.339	4.460	< 0.001	4.54[2.34,8.83]
LYM(*10^9/L)					
≤ 1.085					1
> 1.085	-1.17	0.311	-3.761	< 0.001	0.31[0.17,0.57]
MONO(*10^9/L)					
≤ 0.675					1
> 0.675	1.181	0.308	3.833	< 0.001	3.26[1.78,5.96]
Eos(*10^9/L)					
≤ 0.095					1

Table 4 (continued)

Variable	B	SE	z	p	OR[95%CI]
> 0.095	-0.278	0.301	-0.923	0.356	0.76[0.42,1.37]
Baso(*10^9/L)					
≤ 0.105					1
> 0.105	0.542	1.234	0.439	0.661	1.72[0.15,19.31]
PT(s)					
≤ 10.75					1
> 10.75	0.71	0.511	1.391	0.164	2.03[0.75,5.53]
APTT(s)					
≤ 26.45					1
> 26.45	1.35	0.753	1.792	0.073	3.86[0.88,16.89]
FIB(g/L)					
≤ 4.8					1
> 4.8	0.67	0.345	1.943	0.052	1.96[0.99,3.85]
ALB(g/L)					
≤ 36.15					1
> 36.15	-0.881	0.336	-2.622	0.009	0.41[0.21,0.8]
GGT(U/L)					
≤ 12.5					1
> 12.5	-0.882	0.457	-1.929	0.054	0.41[0.17,1.01]
ALT(U/L)					
≤ 60.5					1
> 60.5	-0.767	0.508	-1.510	0.131	0.46[0.17,1.26]
AST(U/L)					
≤ 23.5					1
> 23.5	0.865	0.401	2.157	0.031	2.38[1.08,5.21]
TBIL(umol/L)					
≤ 13.75					1
> 13.75	0.595	0.326	1.824	0.068	1.81[0.96,3.44]
Cr(umol/L)					
≤ 54.5					1
> 54.5	-0.701	0.333	-2.108	0.035	0.5[0.26,0.95]
BUN(mmol/L)					
≤ 3.83					1
> 3.83	-0.626	0.353	-1.772	0.076	0.53[0.27,1.07]

Annotation: SE: Standard Error; OR: Odds Ratios; 95%CI: 95% Confidence Interval

among other factors. Therefore, there is an urgent need for more simple methods to further predict the occurrence of DVT in order to benefit more patients.

The occurrence of deep vein thrombosis may be related to venous stasis caused by immobilisation after fracture, hypercoagulable states in trauma patients, endothelial injury, and an inflammatory response [25]. Blood coagulation is a finely regulated process, and when inflammation is dysregulated or spontaneous in certain diseases, it can promote thrombotic diseases [26]. Chemotactic factors can induce thrombus formation by forming immune complexes with heparin or other polyanions that activate platelets. In addition, chemotactic factors can alter the charge on the surface of platelets and interact with coagulation factors to regulate the balance between fibrinolysis and coagulation [27]. Some reports have suggested that inflammasome pathway activation occurs in patients with venous thromboembolism, and the main mechanism may involve involvement in inflammatory reactions and oxidative stress, promoting the formation of deep vein thrombosis. Inhibition of inflammasome signalling can reduce venous thrombus formation and vascular damage [28, 29]. Han Jinan et al. [30] experimentally verified that decreased expression of miR-128-3p is beneficial for cell proliferation and migration and inhibits inflammation, apoptosis, and adhesion of human umbilical vein

Table 5 Multivariate binary logistic regression analysis results

Variable	B	SE	z	p	OR[95%CI]
Age (years)	0.039	0.014	2.727	0.006	1.04[1.01,1.07]
WBC(*10^9/L)	0.364	0.059	6.218	< 0.001	1.44[1.28,1.61]
MLR	0.747	0.342	2.182	0.029	2.11[1.08,4.13]

Annotation: SE: Standard Error; OR: Odds Ratios; 95%CI: 95% Confidence Interval

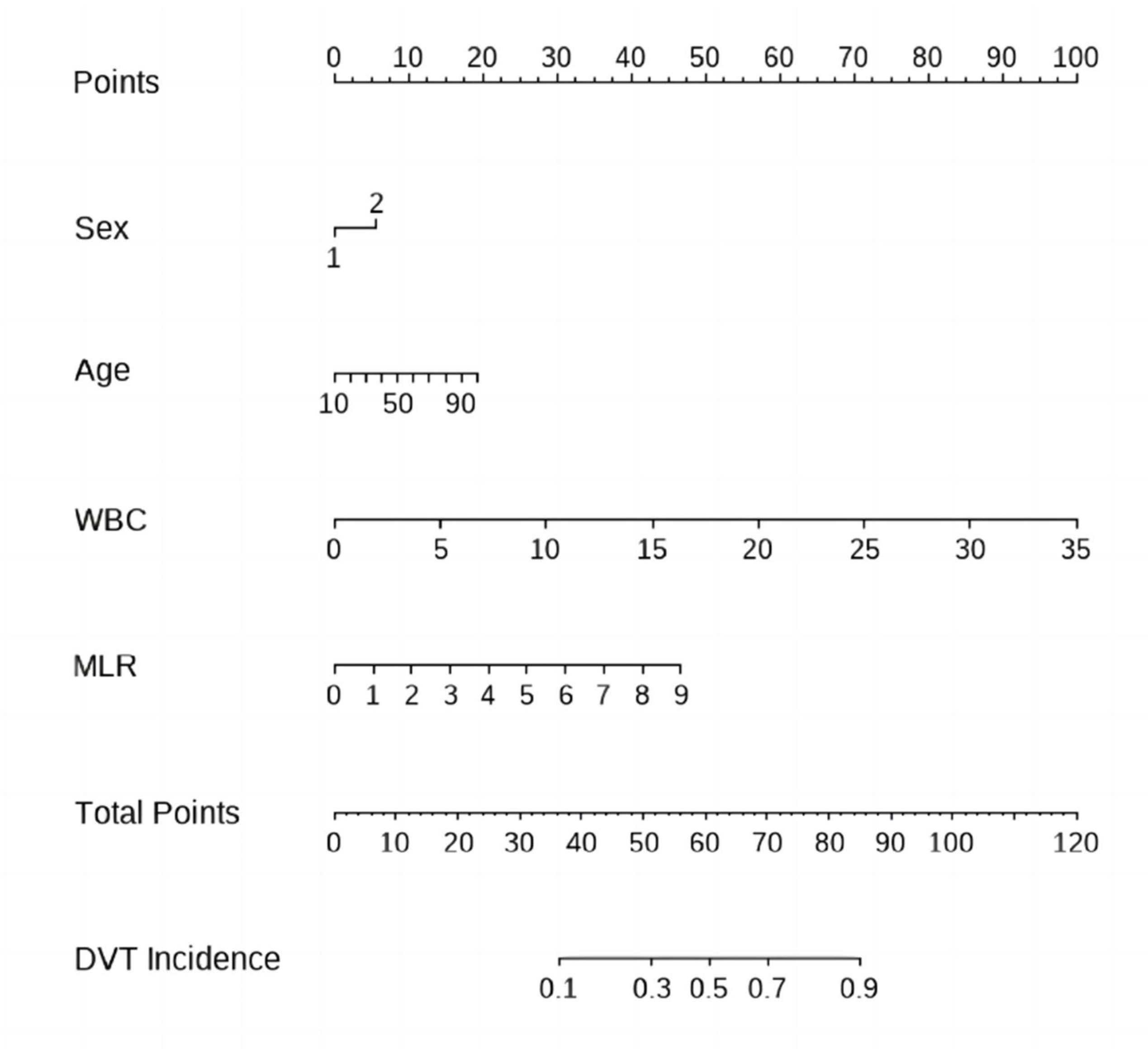

Fig. 4 The nomogram of the study

endothelial cells, thereby reducing the risk of deep vein thrombosis. In addition, NF-κB, as a transcription factor, is one of the central mediators of inflammation, and the NF-κB signalling pathway can regulate pro-inflammatory and pro-coagulation reactions, leading to venous thromboembolism [31]. The formation of neutrophil extracellular traps, accompanied by the release of extracellular decondensed chromatin and pro-inflammatory and prothrombotic factors, is a key factor in the development and progression of thrombotic occlusive diseases [32].

In recent years, more and more literature has focused on the predictive factors of deep vein thrombosis after lower limb fractures. Hongyu Meng et al. [33] conducted a prospective study to verify the predictors of preoperative DVT in isolated calcaneal fractures and proposed that for elderly patients with delayed hospital admission and elevated plasma D-dimer levels, targeted detection of DVT and rapid therapeutic intervention should be emphasized. Kuo Zhao et al. [34] suggested that although anticoagulant therapy is routinely used to prevent DVT formation, the incidence of DVT is still high, and it is recommended to perform ultrasound examination of both lower limbs before surgery, especially for patients with delayed surgery, hypoproteinemia, and 3 or more comorbidities. Although some scholars have proposed predictive factors for DVT in patients with pelvic fractures, no predictive model based on inflammatory indicators has been proposed [35, 36]. At the same time, some scholars have emphasised the great advantages of inflammatory indicators: low cost, quick availability, and early

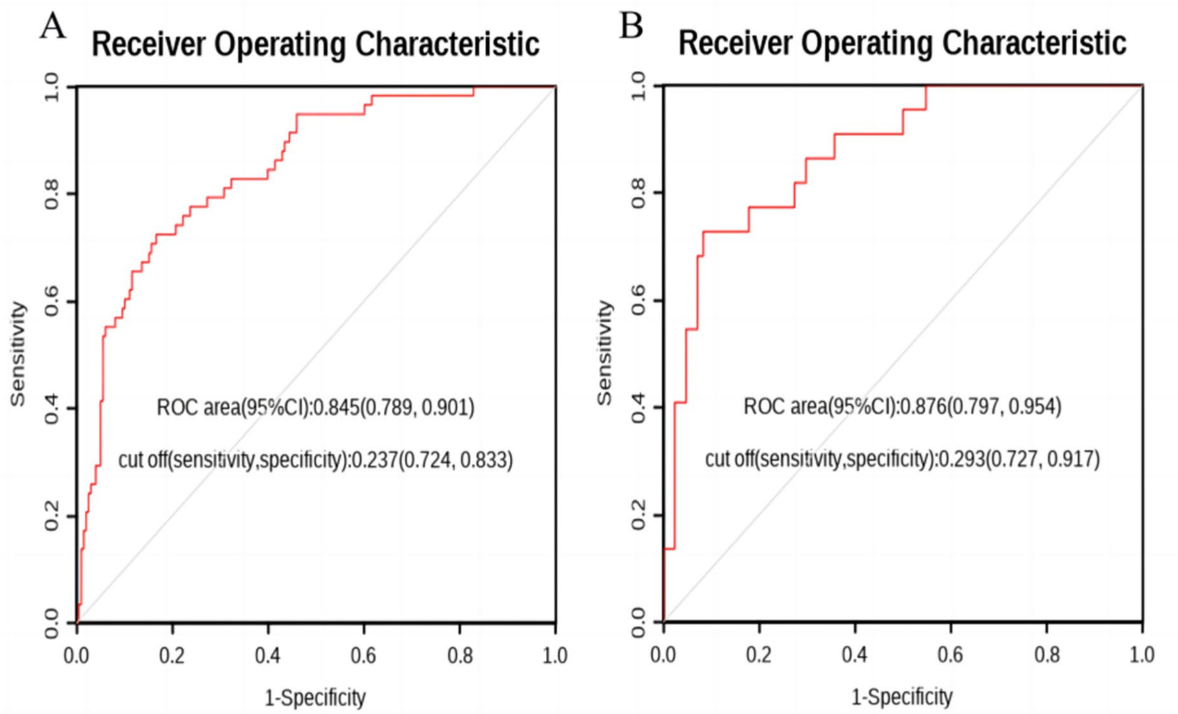

Fig. 5 Receiver operating characteristic of nomogram. **A**. Training test; **B**. Validation test

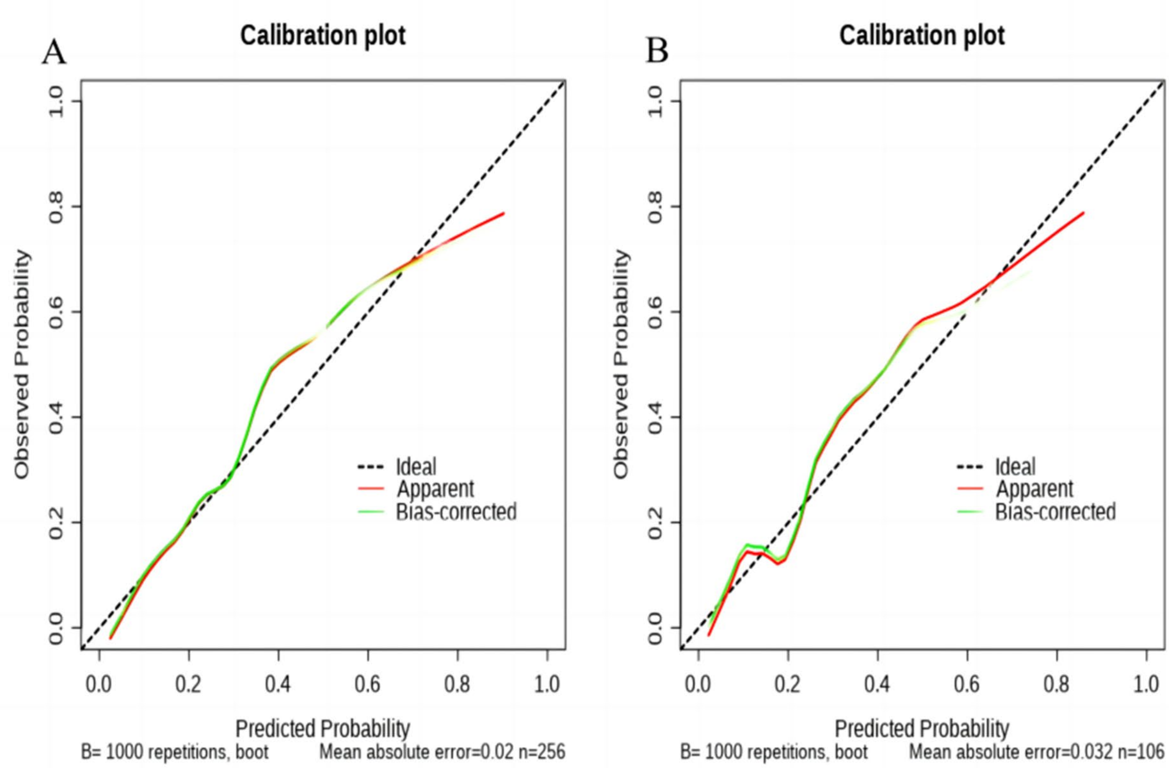

Fig. 6 Calibration plot of the nomogram. **A**. Training test; **B**. Validation test

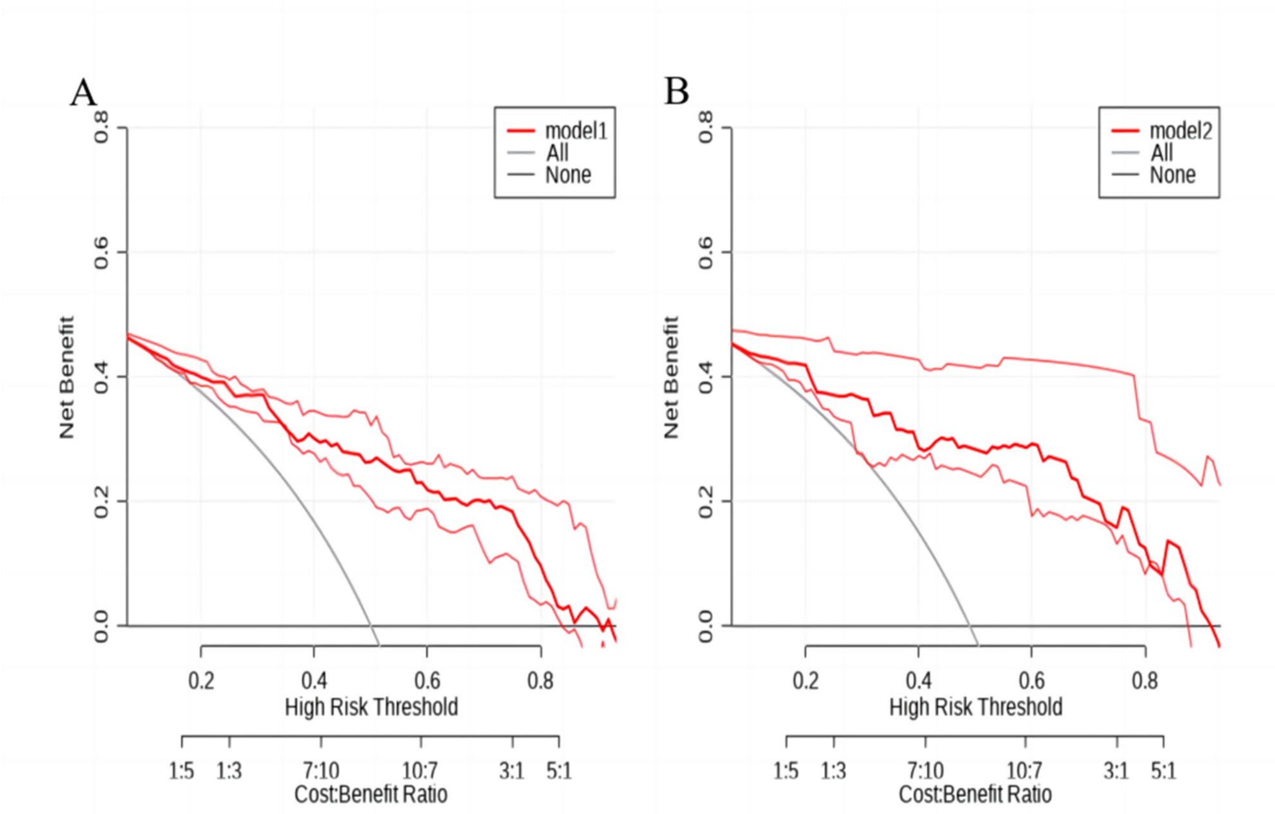

Fig. 7 DCA curve of the nomogram. **A**. Training test; **B**. Validation test

identification of high-risk patients with adverse events [37]. In this study, a nomogram was constructed based on MLR, and the results showed that the model had good predictive performance, small average error, and good clinical benefits. It can help clinicians make relevant predictions and judgments when patients are admitted, and take preventive measures.

This study has several advantages: (1) This study is the first to use inflammatory factors as predictive indicators to construct a column chart, which reflects the characteristics of convenience, speed, and ease of use. (2) This study aims to collect relevant serological examination data at the time of patient admission to achieve early prediction and benefit more patients. (3) The models constructed in the training and validation groups in this study have good predictive performance, small average error, and significant clinical benefits. However, this study also has the following limitations: (1) as a single center study, only internal validation is conducted, and further external validation is required using data from multiple centers; (2) The sample size of this study can be further expanded; (3) We can also explore the mechanism by which inflammatory markers affect the occurrence of deep vein thrombosis through further in vivo and in vitro experiments; (4) This study did not explore the occurrence of postoperative deep vein thrombosis in patients with pelvic fractures.

Conclusion

The Age, WBC, and MLR at the time of admission in patients with pelvic fractures are independent predictive factors for DVT. The nomogram constructed based on MLR can help clinicians assess the probability of DVT occurrence early, achieve early prevention and treatment, and benefit more patients.

Abbreviations

DVT	Deep venous thrombosis
WBC	White blood cell count
RBC	Red blood cell count
HGB	Hemoglobin
MCV	Mean corpuscular volume
MCHC	Mean corpuscular hemoglobin concentration
NC	Neutrophils
LYM	Lymphocyte
MONO	Monocyte
Eos	Eosinophils
Baso	Basophil
ALB	Albumin
AST	Aspartate aminotransferase
ALT	Alanine aminotransferase
TBIL	Total bilirubin
PT	Prothrombin time
APTT	Activated partial thrombin time
FIB	Fibrinogen
Cr	Creatinine

BUN	Blood urea nitrogen
MLR	Monocyte to lymphocyte ratio
OR	Odds ratio
CI	Confidence interval
AUC	The area under the curve
DCA	Decision curve analysis
ROC	Receiver operating characteristic

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Author contributions
RBL designed this study. WCL and HL are responsible for writing articles, conducting statistical analysis, reviewing articles, and creating images. ZH, YHL, JJL, WS and GYD are responsible for collecting data and conducting statistical analysis. All authors reviewed the manuscript. All authors read and approved the final manuscript.

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Data availability
The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the First Affiliated Hospital of Guangxi Medical University Ethics Review Committee (2023-E584-01). Exemption of informed consent from patients with the consent of the ethics committee.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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