

# Development and Prospective Validation of a Novel Risk Score for Predicting the Risk of Lower Extremity Deep Vein Thrombosis Among Trauma Patients

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## Research article

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# Abstract

**Background:** Trauma patients have an increased risk of deep vein thrombosis (DVT). Early identification of patients with a high risk of DVT after trauma is crucial for thromboembolism prophylaxis. We aimed to develop and prospectively validate a novel risk score based on a nomogram to predict lower extremity DVT among trauma patients.

**Methods:** *Clinical data* were collected from 281 trauma patients who were admitted to our trauma center within 24 h of admission from September 2016 to January 2019 to develop a novel DVT risk score. The DVT risk estimates were then calculated prospectively based on the score in a new study cohort from February 2019 to July 2020. The technique of least absolute shrinkage and selection operator (LASSO) was used to select variables for the early prediction of DVT in trauma patients. The DVT risk assessment score (DRAS) was constructed by incorporating related features based on the LASSO analysis and nomogram prediction model. Further, the trauma patients were divided into various risk groups according to the DRAS. The incidence of lower extremity DVT was compared between groups and the discrimination of the DRAS was assessed using the area under the curve (AUC).

**Results:** Based on the LASSO method, eight variables (age, injury severity score, body mass index, D-dimer level, fibrin degradation products, prothrombin time, prealbumin level, and hemoglobin level) were included in the DRAS. A total of 166 trauma patients were enrolled in this prospective study. Increased risk of DVT after trauma was related to higher DRAS. The area under the receiver operating characteristic (ROC) curve for the DRAS was 0.890(0.840–0.939) in the validation cohort. Moreover, the discriminatory capacity of the DRAS was superior to that of each variable independently and the Modified Wells score ( $P<0.05$ ).

**Conclusions:** We developed and prospectively validated the DRAS to predict the risk of lower extremity DVT among trauma patients, which may facilitate early identification of high-risk patients.

## Background

Trauma is a leading cause of death among individuals below 45 years of age and contributes to more than five million deaths worldwide each year [1]. Trauma patients who survive their injuries are at high risk of encountering life-threatening complications, such as respiratory complications, multiple organ dysfunction syndrome, and/or venous thromboembolism (VTE) [2-3]. Therefore, the prediction and prevention of complications following trauma are very important. Recently, deep vein thrombosis (DVT), a type of VTE, has been garnered increasing attention because of its hidden onset and high mortality and disability [4-5]. Because it lacks specific clinical signs and symptoms, DVT cannot be distinguished from superficial thromboangiitis, bacterial skin infection, and cellulitis, as these diseases present with similar clinical manifestations including unilateral limb pain, redness, swelling, and tenderness. Early color Doppler ultrasound scans may be negative in some asymptomatic trauma patients with DVT, reducing the effectiveness of DVT prophylaxis strategies in a subset of trauma patients [6-7]. Although contrast

venography is still considered the definitive test to rule out DVT, it has restricted clinical application for reasons including systemic reaction to the contrast medium, the invasive nature of the procedure, and the large expense of the examination [8]. Moreover, clinical characteristics alone are often unreliable and a large proportion of DVTs after trauma occurring in hospital are asymptomatic, resulting in a reported incidence of DVT in the trauma population between 11.8% and 65% [9]. Although traumatologists increasingly need to understand the relationship of trauma to traumatic DVT, a lack of diagnostic methods for the early identification of patients at high risk of DVT further restricts the prophylaxis strategy. Therefore, a new risk assessment method for the early prediction of DVT following trauma is sorely needed.

The use of clinical characteristics and laboratory tests as the basis of diagnosis have increased in clinical practice. These variables expedite making the clinical diagnosis and improving outcomes[10-11]. Recently, Beilman et al. [12] derived the Wells criteria to effectively rule out the possibility of DVT among trauma patients by using routine clinical characteristics. Yi et al. [13] adopted the Padua Prediction Score and Caprini Risk Assessment System to identify high-risk inpatients with VTE, and both had better predictive ability than independent risk factors, such as age, heart failure, varicose veins, and severe lung disease, among others. Furthermore, Khorasani et al. [14] developed and validated a DVT risk stratification model to evaluate the probability of DVT in hospitalized patients using routine clinical data including the following risk factors: previous DVT, active cancer, and hospitalization  $\geq 6$  days. All of these risk prediction models tend to provide a risk classification to estimate the risk of DVT according to a retrospective analysis of daily electronic medical records. However, concerns exist in these prediction methods, such as Khorasani's score, that use some comprehensive variables, which may not be feasibly assessed by trauma surgeon to quickly evaluate post-traumatic DVT. Therefore, it is reasonable to consider that a risk prediction score should be developed for the early identification of DVT based on routinely available electronic clinical data.

The objective of this study was to develop and prospectively validate a novel risk score for high-risk patients with trauma developing lower extremity DVT based on patient demographic information and routine clinical variables that can be obtained easily within a few hours after admission. We then prospectively validated our score in a new cohort and its performance was externally compared with the Modified Wells score.

## Methods

### Study population

This retrospective cohort study with prospective validation was performed in the Department of Emergency Trauma Center at the Affiliated Hospital of Guizhou Medical University. Patients with trauma in the retrospective cohort and prospective validation cohort were registered during the period from September 2016 to January 2019 and February 2019 to July 2020, respectively. The exclusion criteria were: 1) age <18 years old, 2) death within the first 24 hours after admission, 3) thrombotic disease with

ongoing treatment, and 4) more than 30% of values were missing. The whole leg evaluation and color Doppler ultrasound technique were performed for all trauma patients, and the demographic information and routine clinical test data were collected and extracted from the electronic patient record. The trauma severity of patients was assessed using the injury severity score (ISS) by independent clinicians [15]. Meanwhile, the Modified Wells criteria score was also used to evaluate the validation cohort as an external contrast, because it is currently a commonly used clinical probability assessment tool for clinically suspected DVT [16]. The study was approved by the Institutional Review Board of the Affiliated Hospital of Guizhou Medical University, and all patients or their close relatives provided informed consent.

## **Analysis and imputation of variables**

We collected the following demographic information from the enrolled patients: age, sex, body mass index (BMI), injury mechanism, time from injury to admission (injury-admission time), and injury season. Laboratory variables were collected based on routine blood examinations including D-dimer level, fibrinogen degradation products (FDPs) level, prothrombin time (PT), activated partial thromboplastin time (APTT), total protein, albumin, globulin, prealbumin, serum magnesium, serum calcium, white blood cell count (WBC), neutrophil ratio, basophil granulocyte absolute value, lymphocyte ratio, hemoglobin (Hb) level, red blood cell (RBC) volume, RBC volume distributing width, and platelet count (PLT). The severity of injury was calculated using the ISS trauma score. All clinical and laboratory variables were recorded within the first 24 h after admission. If several measurements for the same indicators were obtained within the first 24 hours, the worst value was adopted.

## **Statistical analysis**

All categorical variables are expressed as numbers and proportions, and differences in these variables between patients with and without DVT were compared using the chi-squared test. Continuous data are presented as means and standard deviations (SD) and were compared using Student's t test or are presented as median with interquartile ranges and were tested with the Mann-Whitney U test. The least absolute shrinkage and selection operator (LASSO) technique was used to screen for the variables with best predictive value from all possible risk factors in retrospective trauma cohort [17]. Multivariate analysis was applied to establish a risk prediction model by incorporating selected features after the LASSO regression. Demographic variables filtered based on  $P < 0.05$  were included in the nomogram prediction model and risk factors associated with thrombotic disease were also included [18]. The  $P$  values, odds ratios, and 95% confidence intervals (CIs) of the selected features were assessed. Harrell's C-index was calculated to assess the predictive ability of the nomogram. To further verify its predictive performance, the prediction nomogram was internally validated using the bootstrapping method. A relatively corrected C-index was calculated based on bootstrapping with 1000 resamples [19]. To evaluate the accuracy of the prediction models, the decision curve analysis (DCA) was performed to estimate the potential clinical predictive ability of the risk model by assessing the threshold probabilities based on the individual data of patients with trauma [20]. Moreover, the predictor was converted into the DVT risk

assessment score (DRAS) based on the nomogram prediction chart. Based on the clinical absolute DVT risk level from the DRAS, the prospective cohort study of 166 patients with trauma were further divided into low-risk, medium-risk, high-risk, and very high-risk groups. The incidence of lower-extremity DVT was compared between groups and the discrimination ability of the DRAS was evaluated using the area under the curve (AUC). All statistical analyses were performed using R software (version 3.6.2) and SPSS 22.0;  $P < 0.05$  was considered statistically significant.

## Results

### Clinical characteristics of the study cohort

In a retrospective cohort study, 678 patients with trauma were initially included in the dataset. Finally, 281 patients with trauma were enrolled after applying the exclusion criteria presented in Additional file 1. The demographic data of all patients are presented in Additional file 2. Among all patients, 197 (70.1%) men and 84 (29.9%) women were included in the retrospective cohort. All patients with trauma had a median age of 46 years and mean age of  $45.94 \pm 14.90$  years. Most patients with trauma had traffic injuries (133/281, 47.33%), and the mean ISS was  $16.26 \pm 4.95$  (range 8–34). Ninety-four (94/678, 13.86%) patients had lower-extremity DVT. The incidence of DVT in patients with  $ISS \geq 16$  was 40.5% (60/148) and the incidence in those with  $ISS < 16$  was 25.6% (34/133). In the prospective validation cohort, 166 patients (117 men and 49 women) were enrolled in the validation analysis. The average age of patients at outcome measurement was  $48.43 \pm 15.85$  years and 54 out of 166 trauma patients developed lower extremity DVT. In total, 51/166 (30.7%) of trauma patients had traffic injuries and 48/166 (28.9%) of patients had fall-related injuries. The incidence of DVT in patients with  $ISS \geq 16$  and  $ISS < 16$  was 50.5% (46/91) and 9.3% (7/75), respectively.

### Feature selection, development, and assessment of the nomogram model

Twenty-five clinical variables were considered as potential features contributing to the prediction of lower extremity DVT (Additional file 2). Eight variables, including age, ISS, BMI, D-dimer levels, FDPs, PT, prealbumin levels, and Hb levels, were selected to construct the prediction nomogram based on non-zero coefficients in the LASSO analysis (Figure 1 & Table 1). Furthermore, a nomogram incorporating all eight variables was established to predict the probability of lower extremity DVT in patients with trauma (Figure 2). In particular, five variables were ultimately demonstrated to have significant predictive value after conducting logistic analysis, which suggested that independent risk factors associated with DVT after trauma were age (OR=2.164, 95% CI 1.133–4.203,  $P=0.020$ ), BMI (OR=2.079, 95% CI 1.116–3.958,  $P=0.023$ ), D-dimer levels (OR=2.812, 95% CI 1.053–7.516,  $P=0.038$ ), FDPs (OR=5.588, 95% CI 2.170–15.125,  $P < 0.001$ ), and PT (OR=2.090, 95% CI 1.018–4.357,  $P=0.046$ ). The receiver operating characteristic (ROC) curve analysis showed that the AUC was 0.852, with 85.1% sensitivity and 75.9% specificity (Additional file 3). Furthermore, the predictive ability was confirmed to be 0.832 in the bootstrapping validation. Therefore, the predicted probability of the nomogram was consistent with the actual probability, and the nomogram had a strongly concordance performance. The calibration plot analysis

suggested that the nomogram showed reasonably good calibration for the prediction probability of DVT among trauma patients (Figure 3). DCA for the DVT prediction nomogram was performed to identify the net benefit of the nomogram; furthermore, its clinical efficiency was assessed by drawing the DCA curve. The DCA of the DVT nomogram demonstrated that the DVT prediction nomogram added more benefit than without the intervention or non-intervention measure within a range of threshold probability of a patient and doctor being >2 and <86%, and the net benefit could achieve maximal performance of the nomogram (Figure 4).

### **Establishment and clinical application of the DRAS**

The DRAS was constructed by combining the eight predictors into a panel based on the nomogram prediction chart. We further divided the DVT risk score into four groups based on DRAS quartiles, low-risk, medium-risk, high-risk and very high-risk groups, and the prospective cohort validation study was designed based on the above groupings. As shown in Figure 5 & Table 2, 96 (57.8%) trauma patients were classified into the low-risk group 9.4% developing DVT; 17 (4.2%) were classified into the medium-risk group with 52.9% developing DVT; 26 (15.7%) were classified into the high-risk group with 65.4% developing DVT; and 27 (16.3%) were classified into the very high-risk group with 70.4% developing DVT. Therefore, the risk of DVT among trauma patients in the prospective cohort study positively correlated with DRAS ( $P<0.05$ ). Furthermore, we also performed the Modified Wells score in the prospective cohort study; the results suggested that six (3.6%) trauma patients were divided into the low-risk group with 33.3% developing DVT, 122 (77.1%) were divided into the medium-risk group with 30.3% developing DVT, and 38 (22.9%) were divided into the high-risk group with 39.5% developing DVT. Moreover, the AUC of the DRAS was 0.879 (0.825–0.932), with 85.20% sensitivity and 76.80% specificity. The DRAS had a better AUC ( $P<0.05$ ) than both the individual clinical predictors and the Modified Wells score (AUC=0.811 [0.743–0.880]), with 68.50% sensitivity and 78.60% specificity Table 3 & Figure 6). The results demonstrated that the DRAS had better predictive value ( $P<0.05$ ).

## **Discussion**

Trauma patients are at increased risk for DVT, which can contribute significantly to morbidity, mortality, and disability as a life-threatening complication following trauma [2,4,7,12]. Despite the innovation in anticoagulant strategy, the morbidity rate of DVT remains very high due to the dramatic increase in the number of patients involved in traumatic events. The estimated annual incidence of VTE has been reported to be 0.1% and there will be approximately 6,000–100,000 deaths of the 1 million VTE patients per year in the United States [21]. The disability-adjusted life years lost as a result of VTE ranks first among all-cause disability globally (DALYs) and VTE has become the third leading cause of cardiovascular death worldwide [22]. Research has showed that early anticoagulant prophylaxis correlates with a 49% and 53% relative risk reduction for the development of symptomatic DVT and asymptomatic DVT, respectively [2,4,5,6,7,9,16]. Therefore, early recognition of patients at high risk of DVT and undertaking prophylaxis strategies to reduce mortality are of great significance. Systematic identification of individual susceptibility to DVT after trauma could provide an opportunity to reduce the

risk of thrombotic complications. Furthermore, a simple, practical, quick, and effective prediction method should be recommended for any trauma surgeon in consideration of the specialty of traumatic disease. In our retrospective study, we found that it was feasible to build a risk prediction score based on routinely available clinical data that could be applied by trauma surgeons to identify high risk DVT among trauma patients. The LASSO technique was utilized to screen the best individual risk factors to build the DVT risk score. Our results demonstrated that the discrimination and calibration of the nomogram deriving from the retrospective cohort are reasonably good, and its C-index was calculated to be 0.852 and was confirmed to be 0.832 in the bootstrapping validation. Meanwhile, the multivariable analysis indicated that the predictive capacity will greatly improve, illustrated by the AUC of 0.852, with 85.1% sensitivity and 75.9% specificity.

In the study, eight predictors including age, BMI, ISS, D-dimer levels, FDPs, PT, prealbumin levels, and Hb levels were incorporated into the prediction score panel. All of the clinical data and laboratory results above are available for trauma surgeons within a few hours of admission. Each variable is strongly associated with DVT in trauma patients. It has previously [23] been described that the D-dimer could further improve both the specificity and the positive predictive value based on age-adjusted cutoff values; therefore, it is not surprising that this was incorporated into our predictive model. The risk factor of ISS has been validated as an independent risk factor for DVT diagnosis, and the incidence of DVT significantly increases with increasing ISS trauma score [24]. With the activation of the coagulation cascade in trauma patients, FDPs [25], PT [26] and Hb [27] become stronger markers for patients who are at high risk of DVT. Prealbumin, which is known as a more sensitive nutritional marker that reflects visceral and somatic nutritional status, would add prognostic information to these established risk predictors because of its nutritional role [28]. Obese patients usually present with a procoagulant state, which may be at markedly increased risk of DVT [29]. From the evidence above, features including age  $\geq 46$  years, ISS  $\geq 17$ , BMI  $\geq 22.5$  kg/m<sup>2</sup>, D-dimer levels  $\geq 13.15$   $\mu$ g/mL, FDPs  $\geq 31.84$   $\mu$ g/mL, PT  $\geq 13.8$  s, prealbumin levels  $\geq 208$  mg/L, and Hb levels  $\geq 121$  g/L were identified as independent predictors of DVT in patients with trauma. The DRAS based on the nomogram prediction chart was developed and we further divided the DVT risk score into four groups based on quartiles of the DRAS: low-risk group, medium-risk group, high-risk group, and very high-risk group.

To further evaluate the prediction efficacy of DRAS, a prospective, double blind validation study was designed to predict incident DVT following trauma. Our results showed that a single predictor could be applied for the early identification of risk of DVT, but the discriminatory ability of a single predictor is limited. When these predictors are integrated into the DRAS, the predictive efficiency significantly improved (AUC=0.879 [0.825–0.932]). Higher DRAS was related to higher risk of DVT among trauma patients in the prospective cohort study. At present, the identification of DVT in trauma patients is usually assessed using the Modified Wells criteria score [12,16]. We also performed this analysis to assess the predictive ability of the Modified Wells score in the same study cohort. The clinical application of the Modified Wells score is relatively limited to predicting DVT among trauma patients and the predictive ability was unsatisfactory for the different Wells risk stratification. Our results fall in line with the studies

of Beilman et al. [12] and Khorasani et al. [16], they derived the Wells score that identifies hospitalized patients at greater risk of developing DVT after severe trauma; however, the disadvantages of the Wells score is that its risk stratification is not sufficient to rule out DVT. The DVT risk prediction models that have been created specifically and widely used for hospitalized patients in determining DVT risk over the past decade. For example, the Trauma Embolic Scoring System (TESS) in Krasné's study investigated five risk factors from 19 variables related VTE markers to objectively quantify the risk of VTE in trauma patients; however, the TESS neglected some lab variables associated with a hypercoagulable state and did not take into account population stratification [30-31]. The Risk Assessment Profile (RAP) [32] score used some comprehensive variables to predict an individual's likelihood to develop DVT, but some of which may not be feasible to measure accurately and evaluate quickly in emergency trauma patients. Caprini's [33-34] risk assessment model aims to employ a thrombosis rating scale to calculate the total risk factor score by incorporating more than 30 risk factors, producing a valid method for identifying patients at risk of DVT or PE; however, the scale appears to be overly complicated for clinic diagnosis. These results indicate that synthetic prediction models play a vital role in the early identification of DVT; however, each of the current prediction models have their own advantages and disadvantages. A reasonable standard for one prediction model may be not applicable in traumatic DVT because of the special status of traumatic disease. However, the DRAS incorporates objective variables including the age, BMI, ISS, D-dimer levels, FDPs, PT, prealbumin levels, and Hb levels in our current study and can streamline the assessment workflow of patients at the highest risk of DVT. The DRAS is more applicable for trauma surgeons and the promotion of earlier management of prophylaxis therapy.

This study has several obvious advantages. First, the LASSO method was more appropriate for the selection of variables and its consolidation of complex clinical data. Moreover, the eight selected predictors can be combined into a panel that can be assessed within a few hours after admission. This is a perfect fit for trauma surgeons to identify patients at high risk of DVT. Second, we performed a prospective validation study to verify the clinical feasibility of the DRAS; the results indicated that the predictive capacity of the DRAS was relatively good, demonstrated by the AUC of 0.879(0.825–0.932), with 85.20% sensitivity and 76.80% specificity. The study also has several potential limitations. First, the retrospective study with prospective validation was performed at a single center, and the sample size of 281 patients in the retrospective cohort and 166 patients in the prospective cohort were relatively small since we used strict inclusion criteria to identify the study population. The inconsistent proportions of the different groups of the DRAS in the prospective validation study may have led to an expected relativity bias. Second, the nomogram only underwent internal validation with a bootstrapping cohort, which also may cause a center bias. Although the DRAS was verified using prospective validation, external validation should be taken into consideration, along with its use in diverse populations and different study centers. Additionally, the outcome of early thromboprophylaxis after the identification of high risk DVT was not observed in an independent prospective cohort. A prospective observational study, preferably in a multicenter design, would be desirable to confirm our findings. Finally, we believe that tapping into the association between clinical variables and the risk of DVT is more reasonable and will ultimately help develop an accurate prediction model for the early identification of high risk DVT after trauma.

# Conclusions

We identified eight clinical characteristics as predictors for DVT after trauma and then derived the DRAS based on nomogram charts. The DRAS has good predictive value for the occurrence of DVT among trauma patients. Once additional prospective validation studies indicate that early thromboprophylaxis significantly improves patient outcome after a high risk of DVT is confirmed by the DRAS, it can be applied in identifying patients at risk of DVT after trauma.

## List Of Abbreviations

DVT – deep vein thrombosis

LASSO – least absolute shrinkage and selection operator

DRAS – DVT risk assessment score

AUC – area under the curve

ROC – receiver operating characteristic

VTE – venous thromboembolism

ISS – injury severity score

BMI – body mass index

FDP – fibrinogen degradation product

PT – prothrombin time

APTT – activated partial thromboplastin time

WBC – white blood cell count

Hb – hemoglobin

RBC – red blood cell

PLT – platelet count

SD – standard deviation

CI – confidence interval

DCA – decision curve analysis

TESS – Trauma Embolic Scoring System

RAP – Risk Assessment Profile

## **Declarations**

### **Ethics approval and consent to participate**

The study protocol was approved by the local ethics committee of the authors' affiliated hospitals and patients provided written informed consent to the study.

### **Consent for publication**

Not applicable.

### **Availability of data and materials**

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

### **Competing interests**

The authors declare that they have no competing interests.

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### **Authors' contributions**

Hong Sun, Lebin Gan, and Zhihong Deng contributed to the data curation, Jiali Sun, Qiang Wang, Guofen Chen contributed the investigation, Jin Deng contributed the project administration, Guoxuan Peng contributed the patient data resources and the software. Guoxuan Peng and Hongxiang Lu contributed writing the original draft. All authors read and approved the final manuscript.

### **Availability of data and materials**

The datasets supporting the conclusions of this article are included within the article and its additional file.

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Not applicable.

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## Tables

Table 1.  
Predictors associated with DVT in trauma patients

Variables	Prediction Model		
	$\beta$	Odd Ratio [95% CI]	p-Value
Age	0.7719	2.164 [1.133-4.203]	0.020
ISS	0.5485	1.731 [0.919-3.293]	0.091
BMI	0.7319	2.079 [1.116-3.958]	0.023
D-Dimer	1.0340	2.812 [1.053-7.516]	0.038
FDP	1.7205	5.588 [2.170-15.125]	<0.001
PT	0.7370	2.090 [1.018-4.357]	0.046
Prealbumin	-0.3380	0.713 [0.349-1.455]	0.351
Hb	-0.2798	0.756 [0.382-1.497]	0.420

**\*Abbreviations:**  $\beta$ , the regression coefficient; ISS, Injury Severity Score; FDP, Fibrinogen Degradation Products; PT, Prothrombin Time;

Table 2.  
Associations of different risk groups based on DRAS and the Modified Wells score with incidence of DVT

DVT Risk classification	DRAS		Modified Wells score	
	Trauma	DVT	Trauma	DVT
Low-Risk	96	9(9.4)	6	2(33.3)
Medium-Risk	17	9(52.9)	122	37(30.3)
High-Risk	26	17(65.4)	38	15(39.5)
Very High-Risk	27	19(70.4)	-	-

Table 3.

Predicted probability of single variable, Modified Wells score, and DRAS

<b>Predictor Model</b>	<b>AUC</b>	<b>Sensitivity</b>	<b>Specificity</b>
<b>Age</b>	0.598(0.507-0.688)	92.60%	25.90%
<b>ISS</b>	0.748(0.672-0.823)	87.00%	61.60%
<b>BMI</b>	0.465(0.370-0.561)	68.50%	19.60%
<b>D-dimer levels</b>	0.812(0.742-0.881)	68.50%	80.40%
<b>FDPs</b>	0.815(0.747-0.882)	81.50%	72.30%
<b>PT</b>	0.673(0.584-0.762)	33.30%	92.90%
<b>prealbumin levels</b>	0.254(0.177-0.331)	16.70%	43.70%
<b>Hb levels</b>	0.274(0.194-0.354)	31.50%	30.40%
<b>Modified Wells score</b>	0.818(0.750–0.886)	68.50%	78.60%
<b>DRAS</b>	0.890(0.840–0.939)	88.90%	75.90%

## Figures

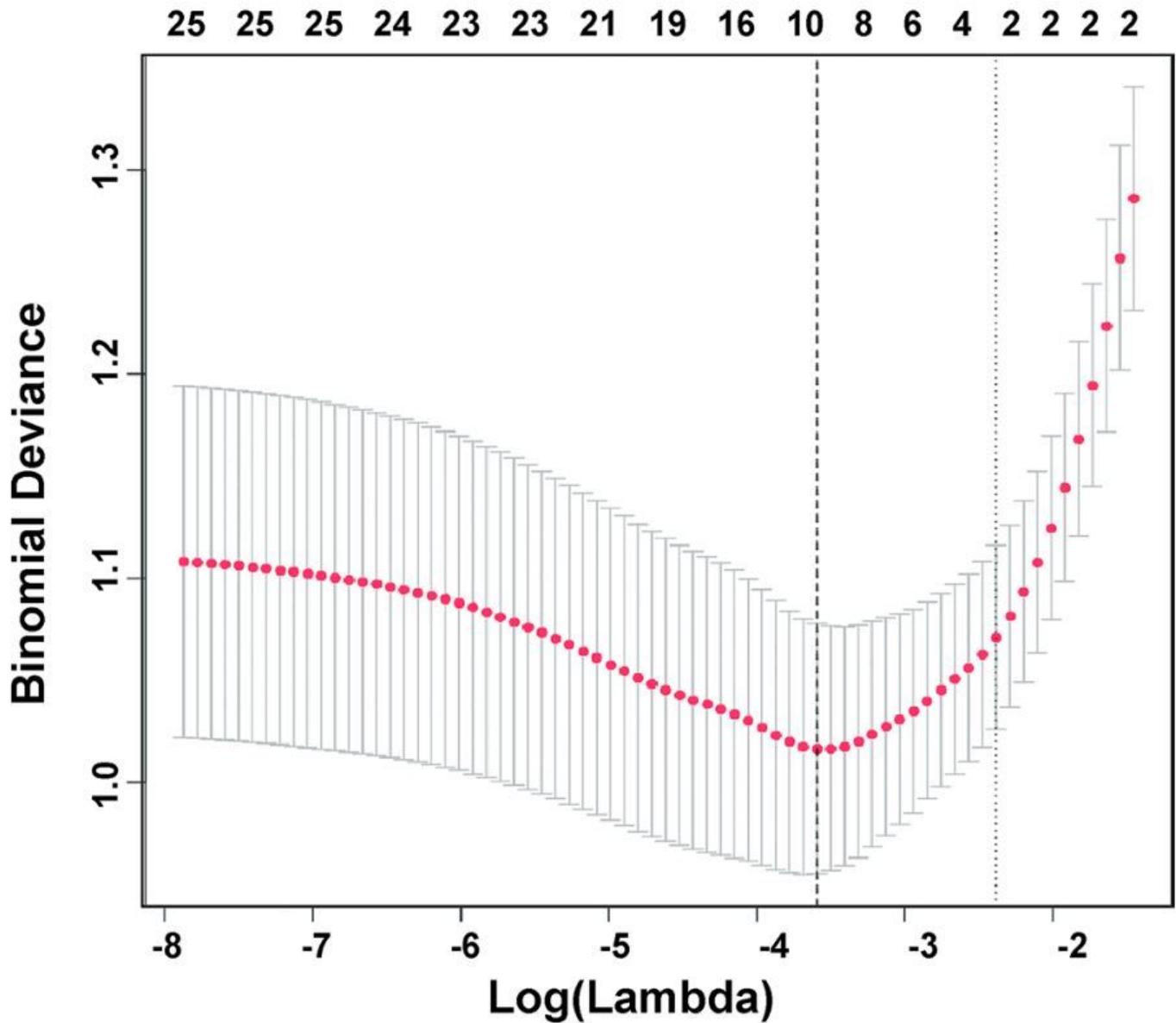
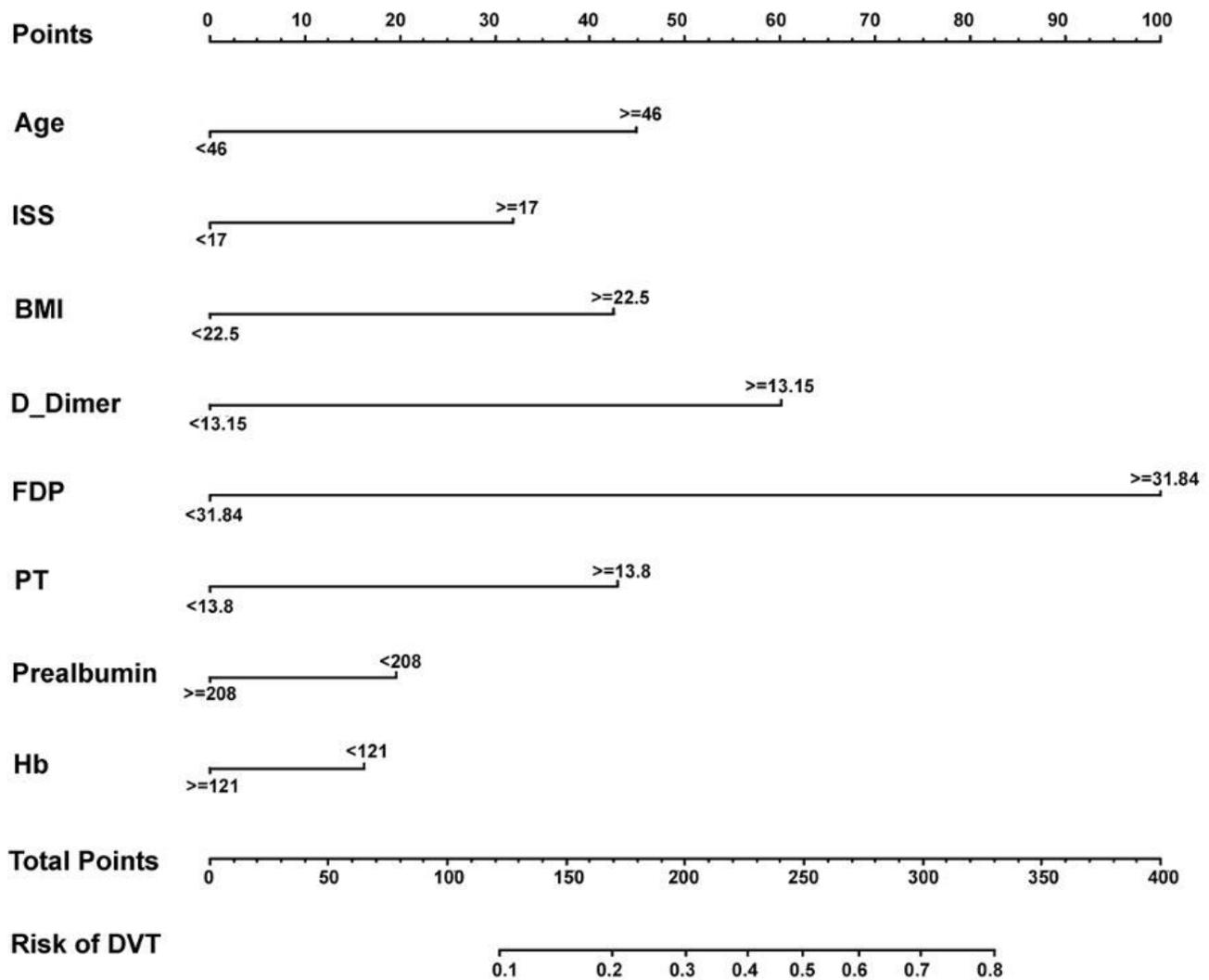


Figure 1

The potential risk factors selected using the LASSO logistic regression model. The maximum lambda parameter was selected using the LASSO model based on the criterion of cross-validation error within one standard error range of the minimum. Different deviance (binomial deviance) values within the range of lambda.



**Figure 2**

Nomogram to predict the probability of DVT in trauma patients. The nomogram was developed by incorporating the eight variables from the retrospective cohort. The DRAS from the nomogram prediction chart can provide a prediction of the likelihood of DVT for an individual trauma patient.

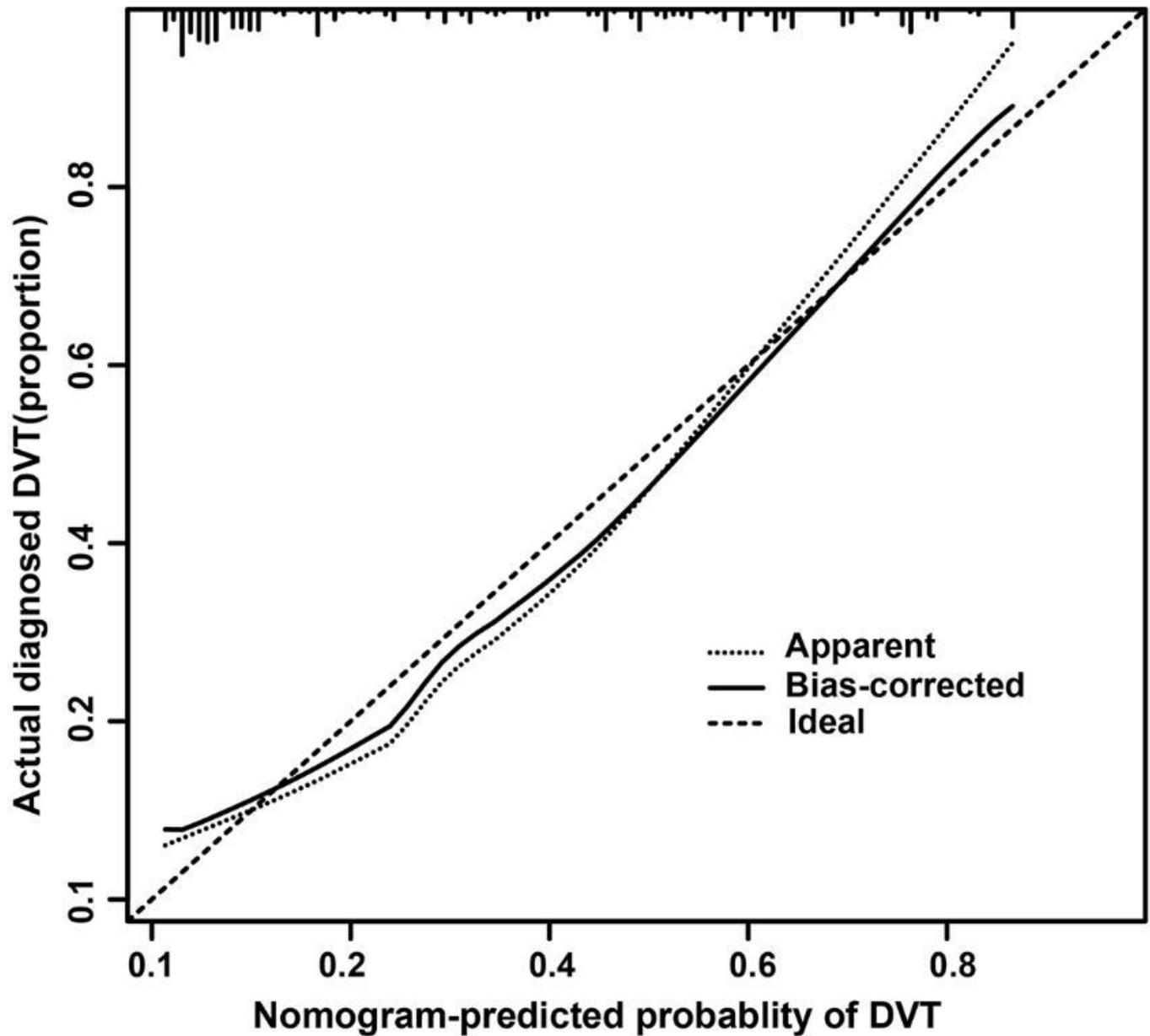


Figure 3

Calibration curves of the DVT nomogram prediction. Mean absolute error=0.028, n=281. Mean squared error=0.00102. Boot=1,000 repetitions. 0.9 Quantile of absolute error=0.049. X-axis: Risk prediction of DVT in trauma patients. Y-axis: Actual diagnosed DVT. The solid bias corrected line was close to ideal line, which represents better prediction capacity.

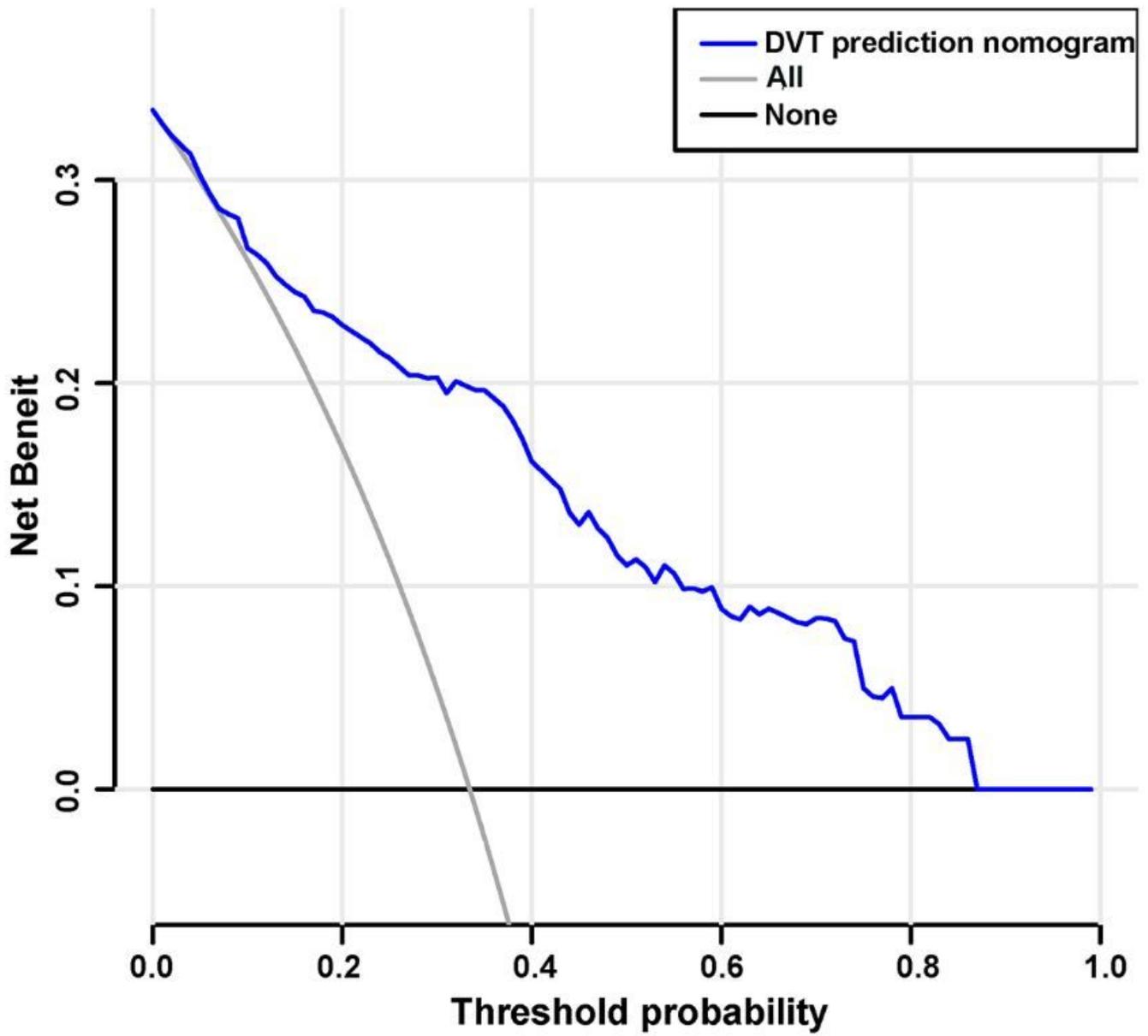


Figure 4

Decision curve analysis for the DVT nomogram. The decision curve showed that the prediction performance for DVT risk can obtain a maximum benefit within the range of 2.0–86.0% for threshold probability. The solid line(Black) represents the assumption that no trauma patients develop DVT.

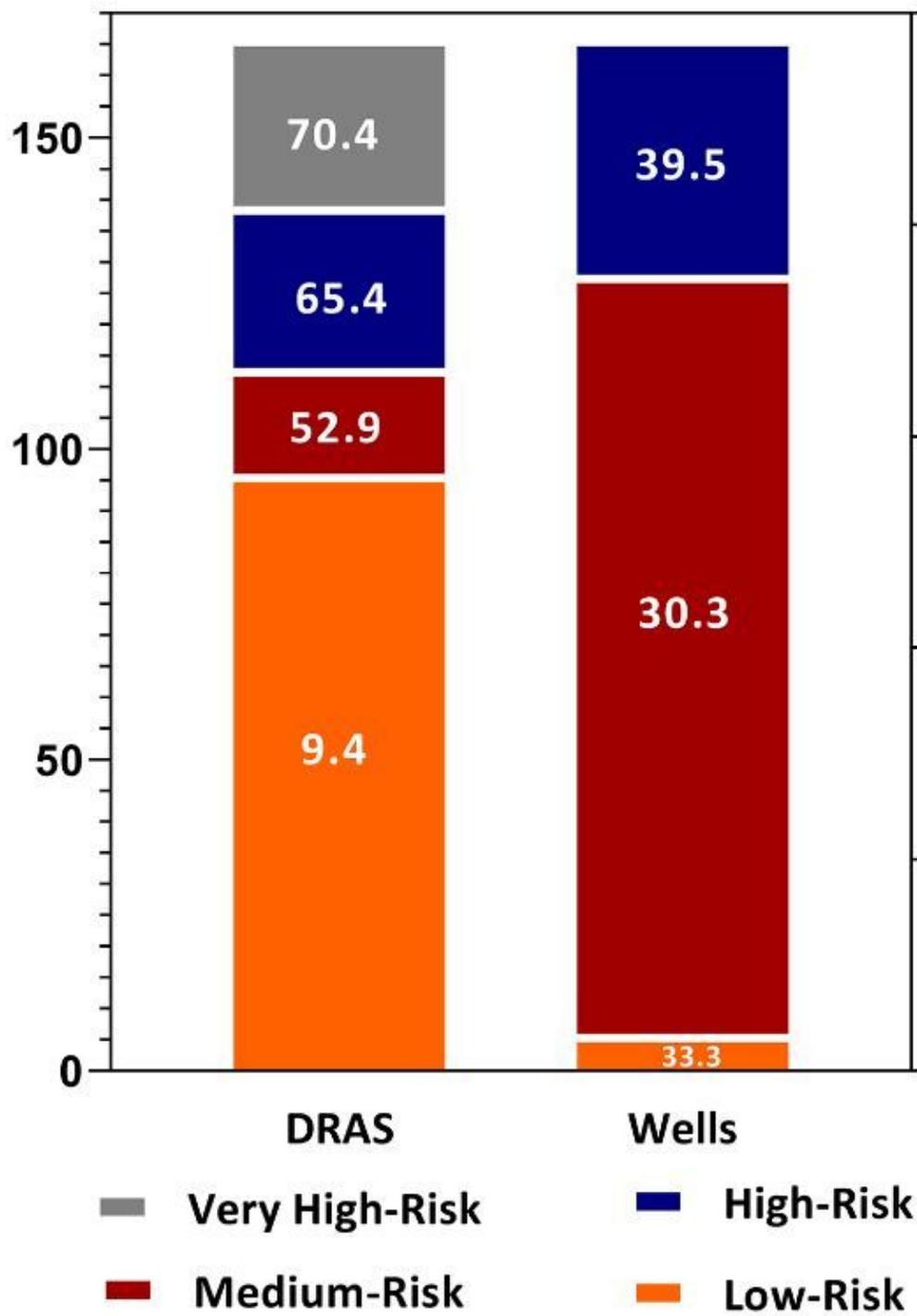


Figure 5

Incidence of DVT for the DRAS and Modified Wells score.

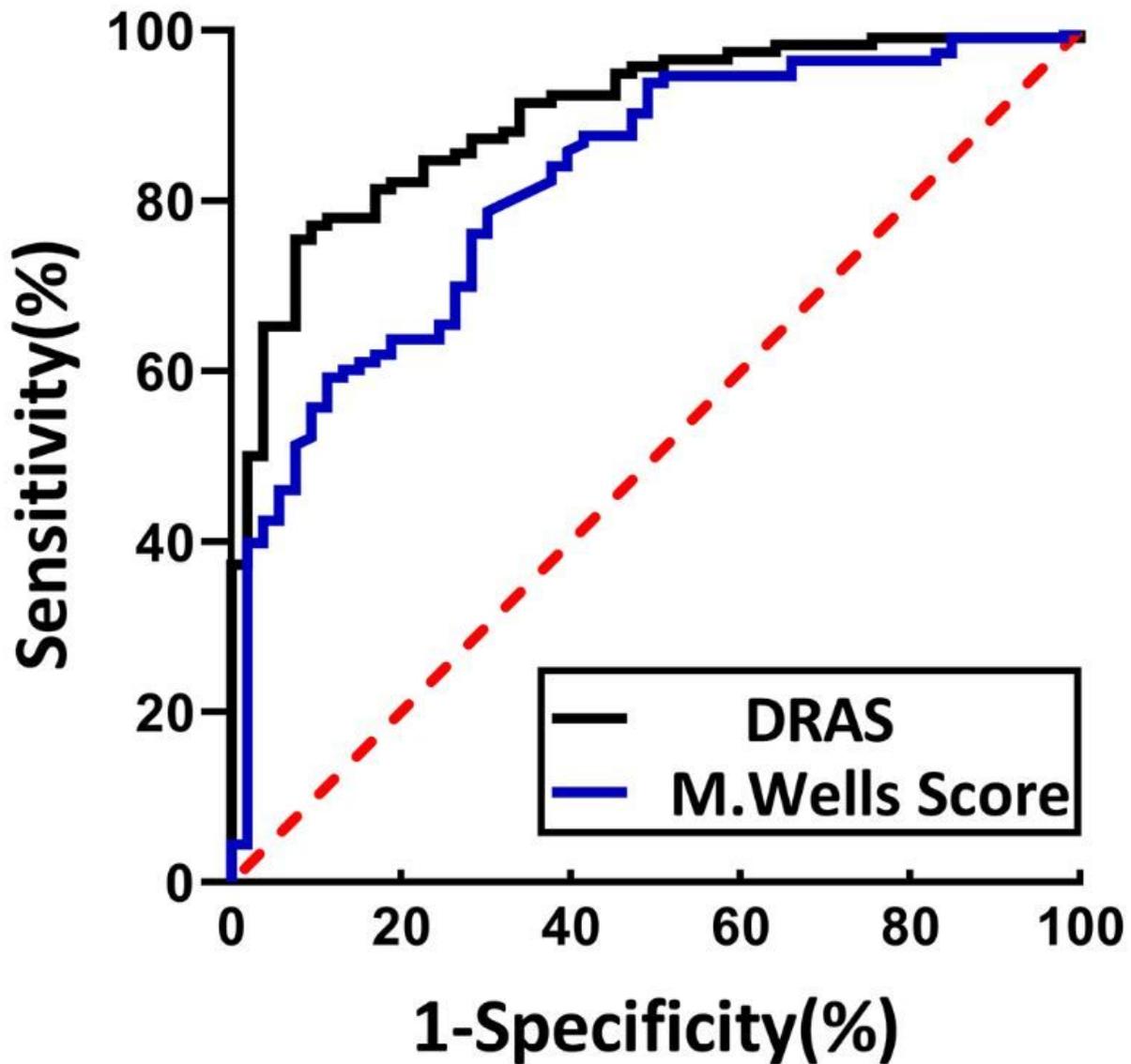


Figure 6

Receiver operating characteristic curve (ROC) analysis of the DRAS and Modified Wells score in the validation dataset (AUC=0.879 vs. 0.811,  $P < 0.05$ ). M.Wells score: Modified Wells score

## Supplementary Files

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