ORIGINAL RESEARCH

Risk Factors of Lower Extremity Deep Vein Thrombosis After Artificial Femoral Head Replacement for Elderly Femoral Neck Fractures and a Nomogram Model Construction

Guoshun Huang, MM; Feng Han, BM; Haifeng Wu, MM; Tao Fan, MM; Weidong Guo, MM

ABSTRACT

Objective • To assess lower extremity deep vein thrombosis (DVT) risk factors after artificial femoral head replacement for elderly femoral neck fractures. A nomogram model was constructed to predict its risk.

Methods • In analyzing 144 participants who underwent artificial femoral head replacement for elderly femoral neck fractures, researchers collected clinical data to identify factors associated with lower extremity DVT. The study collected numerous variables ranging from age and sex to history of lower extremity DVT and use of anticoagulant drugs after surgery. The patients were in two groups: those who developed DVT (n = 62) and those who did not (n = 82). Multivariate logistic regression analysis helped to identify factors influencing the occurrence of DVT after artificial femoral head replacement. The software packages used were R 4.1.0 and RMS.

Results • Univariate and multivariate regression analysis identified age, ASA level, D-dimer of lower limb DVT, ALB, and PLT as predictive risk factors of lower extremity DVT after artificial femoral head replacement for elderly femoral neck fractures. Those risk factors were used to construct a clinical predictive nomogram. The calibration curves for hypertension in patients with OSAHS risk revealed excellent accuracy of the predictive nomogram model. The unadjusted concordance index (C-index) for the model was 0.877 [95% confidence interval (CI), 0.805-0.942]. The AUC was 0.8375002. Decision curve analysis showed that the predictive model could be applied clinically when the threshold probability was 20 to 80%.

Conclusions • The researchers constructed and validated a clinical nomogram to predict the occurrence of lower extremity DVT after artificial femoral head replacement in elderly patients with femoral neck fractures. Age, ASA level, D-dimer, and history of lower limb DVT, ALB, and PLT were demonstrated to be predictive risk factors of lower extremity DVT in this circumstance. This practical prognostic nomogram may help improve clinical decision-making. (*Altern Ther Health Med.* [E-pub ahead of print.])

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INTRODUCTION

Femoral neck fracture (FNF) is a common clinical sub-emergency disease, accounting for about half of hip fractures and 3.58% of total body fractures.[1,2] The prevalence rate has increased significantly in the elderly population, until now about 34% of the elderly suffering from femoral neck fractures.[3] This type of fracture emphasizes early surgical treatment, shortens the bedtime of patients, and reduces the incidence and mortality of postoperative complications.[4] Artificial femoral head replacement is the primary treatment for elderly femoral neck fractures. However, most elderly femoral neck fracture patients are complicated by other diseases; the body is weak, the operation risk is high, and many potential postoperative complications present significant challenges to the operation.

Deep vein thrombosis (DVT) is a common complication of hip fracture in the elderly and a common complication after artificial femoral head replacement.[5] Lower extremity DVT causes fatal pulmonary embolism (PE).[6] According to the latest epidemiology, the total incidence of DVT after hip fracture surgery is 24% - 48%, and about 46% of lower limb DVT will develop into PE.[7] Therefore, for elderly patients with FNF, early detection of the cause and early active prevention of DVT are of significant consequence.

The risk of DVT after artificial femoral head replacement for elderly femoral neck fractures is primarily assessed using a prediction scale.[8,9] Many studies over the years have been conducted to examine the risk factors associated with DVT after this surgical procedure.[10-12] Some of these studies have identified independent risk factors such as a history of atrial fibrillation, acute infection, tumor history, D-dimer fibrinogen, and other factors.[13-17]

Based on these risk factors, a predictive scale has been developed to assess the risk of DVT in the lower extremities following artificial femoral head replacement for elderly femoral neck fractures. Several scales are available for this purpose, including the Caprini Risk Assessment Scale, the Autar Risk Assessment Scale, the Well Risk Assessment Scale, and the Padua Prediction Score Scale.[18-21] These scales have a wide range of applications and are primarily used to predict the occurrence of DVT in patients with tumors. For elderly patients, pertinence is weak after an artificial femoral head replacement.

More recent studies, along with identifying risk factors, have developed an assessment table to predict the early risk of lower extremity DVT following artificial femoral head replacement for elderly femoral neck fractures.[22,23] However, while the scoring scale can provide a general estimation of the DVT risk by calculating the total score and categorizing the risk, it cannot accurately quantify the probability of DVT in the lower extremities.

This study analyzed the risk factors for lower extremity DVT following artificial femoral head replacement in elderly patients with femoral neck fractures. The purpose was to identify independent risk factors and develop a nomogram prediction model that accurately calculates the risk of DVT in the lower extremities. The nomogram provides a quick and easy way to assess the risk and can be used by clinicians to determine appropriate preventive measures. As a multifactor graphical predictive tool, the advantage of a nomogram is that it can provide an individualized estimation for the prediction of the event of interest, which is entirely based on each included factor without averaging or combining within a category. By quantifying the risk of lower extremity DVT, the new nomogram prediction model can help reduce the incidence rate of DVT in elderly patients undergoing artificial femoral head replacement for femoral neck fractures.

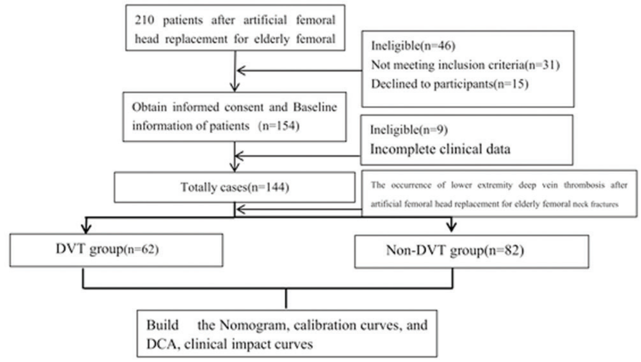
This study analyzed the risk factors for lower extremity DVT following artificial femoral head replacement in elderly patients with femoral neck fractures. Its purpose was to identify independent risk factors and develop a nomogram prediction model to calculate accurately the risk of DVT in the lower extremities. As a multifactor graphical predictive tool, a nomogram can provide an individualized estimation for the prediction of an event based entirely on each included factor without averaging or combining within a category. Nomograms have been used extensively in chronic diseases. It provides a quick and easy way to assess risk and permits clinicians to determine appropriate preventive measures. By quantifying the risk of lower extremity DVT, the new nomogram prediction model can help reduce the incidence rate of DVT in elderly patients undergoing artificial femoral head replacement for femoral neck fractures.

PATIENTS AND METHODS

Study Design

This retrospective study identified risk factors associated with lower extremity DVT following artificial femoral head replacement in elderly patients with femoral neck fractures.

Figure 1. Flow Chart Showing Recruitment



The study included 144 consecutive participants who underwent artificial femoral head replacement for femoral neck fractures between January 2018 and January 2021. The methodology and steps of the study are illustrated in Figure 1.

The required criteria for participants to be included in the study were: (1) individuals aged ≥65 years old; (2) patients who had been diagnosed with a femoral neck fracture in the elderly and had artificial femoral head replacement; (3) no previous history of femoral surgery; (4) unilateral fracture; and (5) availability of complete medical record data.

Potential study participants excluded from the study met one or more of the following exclusion criteria: (1) patients who died or had to undergo other surgeries due to life-threatening complications during the operation; (2) presence of renal parenchyma or renal vascular disease; (3) history of malignant tumor; (4) severe lung disease, neuromuscular disease or mental or psychological disorders; (6) acute or chronic liver, kidney, or digestive system diseases; (7) pregnant or breast-feeding individuals; (8) previous secondary fracture, multiple fractures or old fractures; (9) history of developmental dysplasia of hip joint; (10) patients with severe infectious diseases and coagulation dysfunction; (11) long-term use of anticoagulant drugs or hormones; (12) patients detected with lower extremity DVT before the operation; and (13) incomplete clinical data.

Data Collection and Measurement

This study grouped the patients into two categories: the DVT group (n = 62 cases) and the non-DVT group (n = 82 instances). The grouping was based on whether they developed lower extremity DVT after undergoing artificial femoral head replacement for elderly femoral neck fractures. The researchers gathered various data regarding the characteristics of the subjects, including their age, sex, body mass index, American Society of Anesthesiologists (ASA) classification, fracture side, complications, injury factors, fracture Garden classification, history of lower extremity DVT, use of anticoagulant drugs after surgery, time from injury to hospital, residence, etc. The researchers also collected post-operative data on white blood cell count, hemoglobin levels, hematocrit levels, platelet count, albumin levels, erythrocyte sedimentation rate, prothrombin time, activated partial prothrombin time, fibrinogen, D-dimer levels, and other relevant factors.

Statistical Analysis

Statistical analysis was conducted using SPSS 22.0 software (SPSS Inc. Chicago, IL, USA). The counting data was expressed as a percentage rate, and the comparison between groups was performed using the chi-square test and Fisher's exact probability test. A normality test and variance homogeneity test were applied for the measurement data. Data that followed a normal distribution were expressed by Mean ± SD, and the comparison between groups was carried out using an independent sample t test. Non-normal distribution data were described as M (QL, QU), and the comparison between groups was conducted using the Mann-Whitney U test. The expected maximization method was utilized for imputation to handle missing values.

Multivariate analysis was employed to examine the relationship between the factors related to the occurrence of lower extremity DVT after artificial femoral head replacement in elderly femoral neck fractures, using a binary logistic regression model.

The risk prediction nomograph model of lower extremity DVT after artificial femoral head replacement in elderly femoral neck fractures was established using the R 4.1.0 software package. The bootstrap method was utilized to repeat with 1000 iterations and calculate the consistency index. A calibration curve was plotted to assess the effectiveness of the nomogram model in predicting lower extremity DVT after artificial femoral head replacement in elderly femoral neck fractures. The ROC curve was used to analyze the nomogram model's predictive value for the lower extremity DVT after artificial femoral head replacement for elderly femoral neck fractures in the internal validation group. $P < .05$ indicated a significant difference.

RESULTS

Characteristics of the Subjects

The characteristics in terms of body mass index (BMI), smoking, hypertension, diabetes, coronary heart disease, arrhythmia, cerebral apoplexy, history of myocardial infarction, hyperlipidemia, senile dementia, garden classification of fracture, intraoperative bleeding and time from injury to admission were similar in the two groups ($P > .05$). Still, in terms of sex, gender, ASA classification, fracture side, previous history of DVT, and operation time, the two groups showed significant differences ($P < .05$) (Table 1).

Comparison of Laboratory Biochemical Examination

As shown in the results, the DVT group had higher indexes of D-dimer, platelet (PLT), and albumin (ALB) ($P < .05$). Nevertheless, there was no significant difference in red blood cell-specific volume (HCT), hemoglobin (HB), prothrombin time (PT), total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL) between the two groups ($P > .05$)(Table 2).

Table 1. Baseline Characteristics

	DVT group (n = 62)	non-DVT group (n = 82)	t/χ^2	P value
Age (years)	76.7±6.5	67.8±5.9	8.774	.021
BMI	24.5±3.67	23.9±2.98	3.756	.173
Sex			6.994	.035
Male (n%)	20 (32.26%)	39 (47.60%)		
Female (n%)	42 (67.74%)	43 (52.40%)		
ASA classification			6.894	.033
II	10 (16.13%)	53 (64.63%)		
III	32 (51.61%)	19 (23.17%)		
IV	20 (32.26%)	10 (12.30%)		
Smoking	49 (79.03%)	53 (64.63%)	2.899	.264
Hypertension	18 (29.03%)	24 (29.26%)	2.749	.244
Diabetes	12 (19.35%)	16 (19.51%)	9.163	.061
Coronary heart disease	34 (54.84%)	44 (53.69%)	2.374	.188
Arrhythmia	33 (53.25%)	48 (58.54%)	3.874	.294
Cerebral apoplexy	5(8.06%)	11 (13.41%)	2.743	.293
History of myocardial infarction	25 (40.32%)	47 (57.32%)	1.297	.097
Fracture side			8.455	.022
Left	38 (61.29%)	46 (56.10%)		
Right	24 (38.71%)	36 (43.90%)		
Hyperlipidemia	8 (12.9%)	10(12.20%)	0.139	.729
Senile dementia	5 (8.06%)	5 (6.10%)	0.924	.349
Previous history of DVT	34 (54.84%)	16 (19.51%)	8.442	.02
Garden classification of fracture			0.027	.856
I	0 (0.00%)	2 (2.44%)		
II	12 (19.35%)	11(13.41%)		
III	32 (51.62%)	34 (41.46%)		
V	18 (29.03%)	35 (42.69%)		
Operation time (min)	185.2±76.3	171.9±65.9	5.993	.031
Intraoperative bleeding (eL)	351.2±177.9	352.4±200.4	1.974	.232
Time from injury to admission (min)	150.2±100.3	120.3±110.2	3.364	.067

Table 2. Comparison of Laboratory Biochemical Examination Between Two Groups

	DVT group (n = 62)	non-DVT group (n = 82)	t/χ^2	P value
HCT(%)	41.10(4.75)	41.20(5.9)	0.026	.829
Hb(gL)	133.00(20.00)	138.00(22.00)	2.124	.198
D-dimer	0.20(0.20)	0.16(0.17)	11.885	.007
PT(s)	11.10(0.95)	11.20(0.90)	0.944	.352
PLT($\times 10^9$/L)	244.63(22.74)	178.80(20.54)	5.993	.031
TC(mmoVL)	4.61(1.28)	4.54(1.24)	1.674	.213
TG(mmo/L)	1.41(0.90)	1.29(1.04)	0.924	.926
LDL	2.82(1.00)	2.72(0.92)	2.553	.336
HDL	1.25(0.36)	1.24(0.40)	0.037	0.852
ALB	22.5(6.7)	34.5(5.9)	8.442	.023

Abbreviations: HCT, Red blood cell-specific volume; Hb, Hemoglobin; PT, prothrombin time; PLT, Platelet; TC, total cholesterol; TG, triglyceride; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; ALB, albumin.

Univariate Analysis

As shown in Table 3, the results of the univariate analysis showed that age ≥ 70 years old, ASA grade 3, previous history of lower limb DVT, cerebral vascular disease, time from injury to hospital ≥ 24 h, serum ALB<35 g/L, D-dimer ≥ 0.5 mg/L, PLT ≥ 262×10^9 /L in the DVT group were significantly higher than that of the non-DVT group ($P < .05$).

Multivariate Analysis

The multivariate analysis confirmed predictive factors associated with lower extremity DVT after artificial femoral head replacement for elderly femoral neck fractures (Table 4). Independent predictive factors included: age ≥ 70 (95% confidence interval (CI) 1.292 ~ 2.930; $P = .027$), ASA level 3 (95% CI 1.193 ~3.695; $P = .031$), previous history of lower limb DVT (95% CI 1.126 ~ 4.321; $P = .034$), ALB <35 g/L (95% CI 1.160~3.916; $P = .026$), D-dimer ≥0.5 mg/L (95% CI 1.140~3.423; $P = .027$), and PLT ≥ 262 × 10^9/L (95% CI 1.343~3.494; $P = .012$).

Table 3. Univariate Analysis

Variable	DVT group (n = 62)	non-DVT group (n = 82)	χ2	*P* value
Age			7.912	.015
>70	44 (70.97%)	32 (39.02%)		
<70	18 (29.03%)	50 (60.98%)		
Sex			6.954	.035
Male (n%)	20 (32.26%)	39 (47.60%)		
Female (n%)	42 (67.74%)	43 (52.40%)		
BMI			0.178	.631
<24kg/m²	28 (45.16%)	40 (48.78%)		
>24kg/m	34 (54.84%)	42 (51.22%)		
ASA classification			75.548	.002
III	32 (51.61%)	19 (23.17%)		
IV	20 (32.26%)	10 (12.30%)		
Fracture side			3.465	.072
Left	38 (61.29%)	46 (56.10%)		
Right	24 (38.71%)	36 (43.90%)		
Previous history of lower limb DVT			12.989	.020
Yes	24 (38.71%)	2 (2.44%)		
No	38 (61.29%)	80 (97.56%)		
Diabetes			1.574	.223
Yes	12 (19.35%)	16 (19.51%)		
No	50 (80.65%)	66 (80.49%)		
Hyperlipidemia			0.139	.729
Yes	8 (12.9%)	10 (12.20%)		
No	54 (87.1%)	72 (87.80%)		
Hypertension			0.008	.954
Yes	18 (29.03%)	24 (29.26%)		
No	44 (70.97%)	58 (70.74%)		
Cerebral vascular disease			12.734	.002
Yes	40 (64.52%)	32 (39.02%)		
No	22 (35.48)	50 (60.98%)		
Senile dementia			0.934	.359
Yes	5 (8.06%)	5 (6.10%)		
No	57 (91.94%)	77 (93.90%)		
Garden classification of fracture			0.027	.846
I	0 (0.00%)	2 (2.44%)		
II	12 (19.35%)	11 (13.41%)		
III	32 (51.62%)	34 (41.46%)		
V	18 (29.03%)	35 (42.69%)		
Time from injury to admission			4.364	.047
≥ 24h	50 (80.65%)	47 (57.32%)		
<24h	12 (19.35%)	55 (42.68%)		
Operation time			0.944	.349
≥ 3h	57 (91.94%)	77 (93.90%)		
<3h	5 (8.06%)	5 (6.10%)		
Hb			0.567	.437
≥60g/L	21 (33.87%)	29 (35.37%)		
<60g/L	41 (66.13%)	53 (64.63%)		
ALB			8.794	.013
≥35g/L	20 (32.26%)	46 (59.10%)		
<35gL	42 (67.74%)	36 (40.90%)		
D-dimer			10.143	.011
≥0.5mg/L	41 (66.13%)	32 (39.02%)		
<0.5mg/L	21 (33.87%)	50 (60.98%)		
PLT			6.536	.020
≥262x10⁹/L	22 (35.48%)	12 (14.63%)		
<262x10⁹/L	40 (64.52%)	70 (85.37%)		

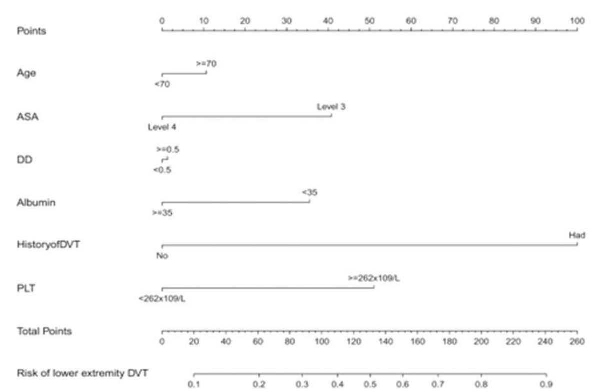
Abbreviations: Hb, Hemoglobin; AL,: albumin; PLT, Platelet.

Table 4. Multivariate Analysis

Variable	B	SE	Wald/χ2	*P* value	OR	95% CI
Age ≥ 70	0.626	0.239	7.256	.027	1.862	1.292 ~ 2.930
ASA level 3	0.732	0.393	6.529	.031	2.079	1.193 ~3.695
Previous history of lower limb DVT	0.791	0.357	5.076	.034	2.184	1.126 ~ 4.321
Time from injury to admission ≥ 24h	0.435	0.349	1.582	.220	1.540	0.797~2.983
Sex (Female)	0.693	0.213	11.330	.211	1.990	1.340~2.957
ALB <35g/L	0.761	0.322	5.894	.026	2.129	1.160~3.916
D-dimer≥0.5mg/L	0.685	0.292	5.749	.027	1.974	1.140~3.423
PLT≥262x10⁹/L	0.778	0.255	9.846	.012	2.165	1.343~3.494
Cerebral vascular disease	0.665	0.399	2.855	.092	1.935	0.898~4.137

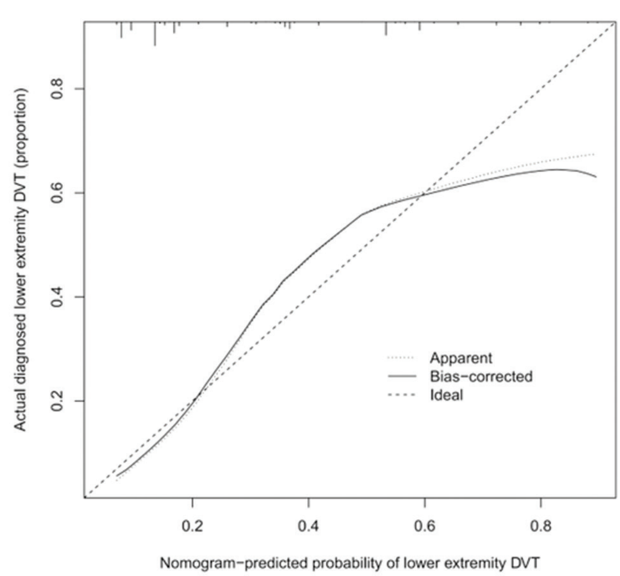
Abbreviations: ALB, albumin; PLT, Platelet.

Figure 2. The Nomogram for Predicting the Risk of Lower Extremity Deep Vein Thrombosis After Artificial Femoral Head Replacement for Elderly Femoral Neck Fractures



Abbreviations: DD, D-dimer; DVT, deep vein thrombosis; PLT, Platelet.

Figure 3. The Calibration Curves for Predicting the Risk of Lower Extremity Deep Vein Thrombosis After Artificial Femoral Head Replacement for Elderly Femoral Neck Fractures



Construction of the Nomogram

After careful consideration, six distinct risk factors were selected for the nomogram model to predict the likelihood of lower extremity DVT following artificial femoral head replacement in elderly patients with femoral neck fractures (see Figure 2). These risk factors included age, ASA level, D-dimer, history of lower limb DVT, ALB, and PLT levels. The nomogram provides a comprehensive visual representation, with total points ranging from 0 to 260 and predictive risk rates ranging from 0.1 to 0.9. It is important to note that as the total points increase, so does the corresponding risk.

Validation of the Nomogram

The nomogram's calibration plot is shown in Figure 3. The nomogram's unadjusted concordance index (C-index) was 0.877, with a 95% CI of 0.805–0.942. The nomogram's area under the curve (AUC) was 0.8375002, as shown in Figure 4. These findings demonstrate that the nomogram can effectively predict the risk of lower extremity DVT following artificial femoral head replacement in elderly individuals with femoral neck fractures.

Figure 4. ROC Curves for Predicting the Risk of Lower Extremity Deep Vein Thrombosis After Artificial Femoral Head Replacement for Elderly Femoral Neck Fractures

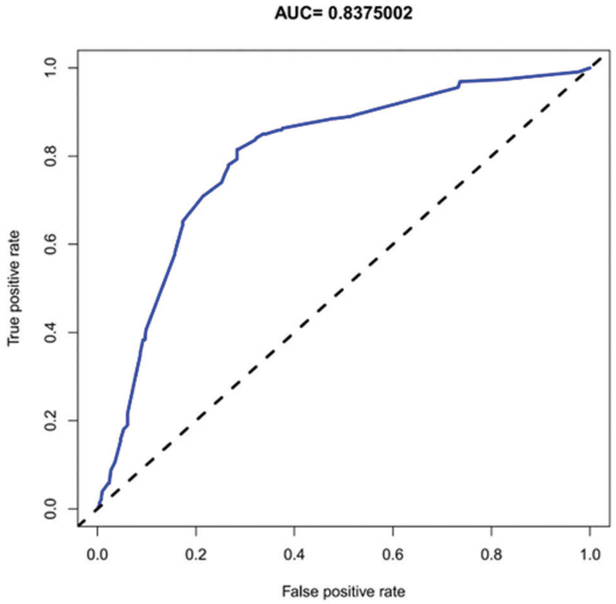
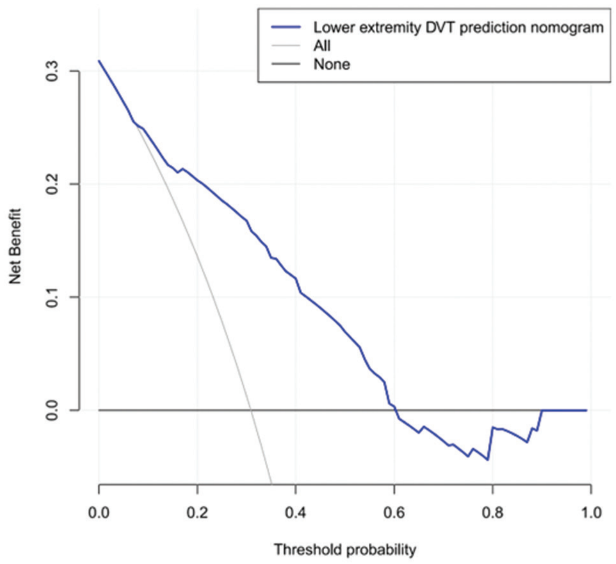


Figure 5. Decision Curve Analysis for the Nomogram



Clinical Use

DCA demonstrated that if the risk threshold of a patient is between 20% and 75%, there will be more net benefit in using the nomogram to decide whether or not to conduct treatment. The decision curve demonstrated that the nomogram had a favorable clinical utility. (Figure 5).

DISCUSSION

The researchers constructed a predictive nomogram model to predict the likelihood of lower extremity DVT following artificial femoral head replacement in elderly patients with femoral neck fractures. Age, ASA level, D-dimer, history of lower limb DVT, ALB, and PLT were identified as independent risk factors for lower extremity DVT after artificial femoral head replacement in elderly patients with femoral neck fractures. The calibration plot demonstrated that this nomogram model exhibited excellent accuracy and clinical applicability, as indicated by its high C-index and AUC values. The decision curve analysis further confirmed the clinical usefulness of this nomogram in predicting the risk of lower extremity DVT after artificial femoral head replacement in elderly patients with femoral neck fractures. Moreover, this model can enable early identification of individuals at high risk.

In this study, age is an independent risk factor for deep venous thrombosis of lower limbs. Research by Kawai et al.[24] showed that elderly patients who undergo artificial femoral head replacement for femoral neck fractures have an increased risk of developing DVT. The risk of venous thromboembolism (VTE) in these patients was six times higher compared to non-elderly patients. Moreover, for elderly individuals with femoral neck fractures, being above 75 was identified as a risk factor for developing DVT in the lower limbs (P = .041, OR 1.075, 95% CI 1.002-1.110).[25] Another study conducted by Galanaud et al. also supports these findings, indicating that individuals aged 70 and above are at an independent risk factor for DVT in the lower limbs after undergoing artificial femoral head replacement for femoral neck fractures.[26]

Many studies have indicated that advanced age poses a risk of developing DVT in the lower limbs after artificial femoral head replacement for elderly individuals with femoral neck fractures. However, there remains considerable debate regarding age stratification about this risk. In elderly patients, the affected limb experiences reduced blood flow due to trauma, leading to sluggish circulation. Furthermore, as individuals age, their muscle volume decreases, resulting in a decline in muscle pump function, further impeding blood flow. This combination of factors contributes to blood stasis and thrombosis. Additionally, elderly patients tend to engage in less post-traumatic physical activity, exacerbating the potential condition. With advancing age, diet and heart function decline, as does the elasticity of blood vessel walls. Consequently, circulation capacity diminishes, and blood flow slows down, making it more likely for DVT to occur. Moreover, the inflammatory response triggered by trauma activates the inflammation-coagulation pathway in the body, ultimately leading to the formation of DVT in the lower limbs due to the combined effect of multiple factors.[27,28] Therefore, early measures should be implemented to prevent the development of DVT in the lower limbs of elderly individuals with femoral neck fractures.

The presence of anesthesia score (ASA 3) is identified as a separate risk factor for DVT in this study. Moreover, it is observed that the incidence of DVT significantly increases with an ASA 3 score. Whiting et al.[29] have emphasized that the ASA score is a comprehensive evaluation index for assessing patients' physical condition and surgical risk. However, it is important to note that the ASA score is influenced by various factors,[30,31] which has led to ongoing debates regarding its use in thrombosis risk assessment. Further research is required, particularly studies that strictly control variables, to establish reliable conclusions.

Low albumin is an independent risk factor for DVT in the lower extremities. This study showed that the incidence of DVT in patients with high albumin levels was only 0.761 times that in patients with low albumin (OR 2.129, 95% CI 1.160~3.916). Patients' digestive and absorption functions decline as they age, leading to poor nutritional status. In addition, stress and tissue inflammation following fractures and injuries contribute to albumin decomposition, resulting in decreased levels.[32,33] Therefore, it is crucial to supplement albumin promptly in elderly patients with femoral neck fractures who have low protein levels to prevent the development of DVT in the lower limbs.

The dimer is produced when cross-linked fibrin breaks down. An increase in dimer levels often indicates increased blood clotting and activation of the fibrinolytic system in the body.[34] Currently, a negative D-dimer result can be used as an exclusion criterion to rule out venous thrombosis, although there is still some debate surrounding this.[35] Alexander et al.[36] showed that the risk of DVT in patients with D-dimer >0.3 mg/L was 3.3 times higher than in patients with D-dimer<0.3 mg/L. Researchers increasingly believe that setting the positive cut-off value of DVT occurrence based on a large sample may be a more accurate means of exclusion or prediction.[35,37,38] Therefore, it is essential to monitor the D-dimer levels closely in elderly patients who have undergone artificial femoral head replacement following neck fractures, particularly within the first day after surgery. If there is a significant increase in D-dimer levels, proactive anticoagulant therapy should be initiated.

Study Limitations

This study has a few shortcomings. First, this study is a single-center retrospective case-control study with a small sample size. There may be errors resulting from selection or recall bias, which could limit the generalizability of the findings. The observations in this study need to be verified in a study with a larger sample size from multiple centers. Second, this study does not analyze all collected indicators, potentially affecting the accuracy of the model's predictions. Third, while this study received internal evaluation and verification of the model, there was a lack of external validation. A more extensive, multi-center study is required to verify its applicability.

CONCLUSION

In conclusion, this study developed a visual individualized model for predicting DVT in the lower extremities after artificial femoral head replacement in elderly patients with femoral neck fractures. The aim was to provide quantitative indicators for assessing DVT in the lower limbs following the replacement procedure and identify individuals who may require early prevention measures. The resulting nomogram, which demonstrated remarkable discrimination and calibration, should prove helpful for making therapeutic decisions and conducting patient surveillance.

ETHICAL COMPLIANCE

The Ethics Committee of the General Hospital of Tisco approved this study. The study complied with the Declaration of Helsinki.

CONFLICT OF INTEREST

The authors have no potential conflicts of interest to report relevant to this article.

AUTHOR CONTRIBUTIONS

GH and WG designed the study and performed the experiments; FH and HW collected the data, FH, HW, and TF analyzed the data; GH and WG prepared the manuscript. All authors read and approved the final manuscript.

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REFERENCES

1. Florschutz AV, Langford JR, Haidukewych GJ, Koval KJ. Femoral neck fractures: current management. *J Orthop Trauma*. 2015;29(3):121-129. doi:10.1097/BOT.0000000000000291
2. Bernstein EM, Kelsey TJ, Cochran GK, Deafenbaugh BK, Kuhn KM. Femoral Neck Stress Fractures: An Updated Review. *J Am Acad Orthop Surg*. 2022;30(7):302-311. doi:10.5435/JAAOS-D-21-00398
3. Maffulli N, Aicale R. Proximal femoral fractures in the elderly: a few things to know, and some to forget. *Medicina-Lithuania*. 2022;58(10):1314. doi:10.3390/medicina58101314.
4. Xu DF, Bi FG, Ma CY, Wen ZF, Cai XZ. A systematic review of undisplaced femoral neck fracture treatments for patients over 65 years of age, with a focus on union rates and avascular necrosis. *J Orthop Surg Res*. 2017;12(1):28. doi:10.1186/s13018-017-0528-9
5. Fischer H, Maleitzke T, Eder C, Ahmad S, Stöckle U, Braun KF. Management of proximal femur fractures in the elderly: current concepts and treatment options. *Eur J Med Res*. 2021;26(1):86. doi:10.1186/s40001-021-00556-0
6. Chu CC, Haga H. Venous thromboembolism associated with lower limb fractures after trauma: dilemma and management. *J Orthop Sci*. 2015;20(2):364-372. doi:10.1007/s00776-014-0690-4
7. Saadat GH, Alsoof D, Ahmad B, Butler BA, Messer TA, Bokhari F. Incidence, risk factors and clinical implications of postoperative urinary tract infection in geriatric hip fractures. *Injury*. 2022;53(6):2158-2162. doi:10.1016/j.injury.2022.03.012
8. Li T, Lv M, Li Q. [Comprehensive prophylaxis for deep venous thrombosis after proximal femur fractures in geriatric patients]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2008;22(4):453-455.
9. Yu X, Wu Y, Ning R. The deep vein thrombosis of lower limb after total hip arthroplasty: what should we care. *BMC Musculoskelet Disord*. 2021;22(1):547. doi:10.1186/s12891-021-04417-z
10. Fu YH, Liu P, Xu X, et al. Deep vein thrombosis in the lower extremities after femoral neck fracture: A retrospective observational study. *J Orthop Surg (Hong Kong)*. 2020;28(1):2309499019901172. doi:10.1177/2309499019901172
11. Wu X, Shen Y, Chen Y, Zhang H, Jiang M. Comparison of clinical efficacy of artificial femoral head replacement and total hip replacement in the treatment of femoral neck fracture in the elderly. *Minerva Surg*. 2021;76(5):484-485. doi:10.23736/S2724-5691.21.08868-7
12. Mioc ML, Prejbeanu R, Vermesan D, et al. Deep vein thrombosis following the treatment of lower limb pathologic bone fractures - a comparative study. *BMC Musculoskelet Disord*. 2018;19(1):213. doi:10.1186/s12891-018-2141-4
13. Tsuda Y, Yasunaga H, Horiguchi H, Fushimi K, Kawano H, Tanaka S. Effects of fondaparinux on pulmonary embolism following hemiarthroplasty for femoral neck fracture: a retrospective observational study using the Japanese Diagnosis Procedure Combination database. *J Orthop Sci*. 2014;19(6):991-996. doi:10.1007/s00776-014-0607-2
14. Rajaganeshan R, Dussa CU, Sahni V. National survey in the United Kingdom of prophylaxis of deep vein thrombosis for patients with fracture of the neck of the femur. *Injury*. 2006;37(8):721-726. doi:10.1016/j.injury.2005.12.020
15. Wilson D, Cooke EA, McNally MA, Wilson HK, Yeates A, Mollan RA. Altered venous function and deep venous thrombosis following proximal femoral fracture. *Injury*. 2002;33(1):33-39. doi:10.1016/S0020-1383(01)00137-1
16. Pan Y, Zhao J, Mei J, Shao M, Zhang J, Wu H. Evaluation of nonpermanent inferior vena cava filter placement in patients with deep venous thrombosis after lower extremity fracture: A single-center retrospective study. *Phlebology*. 2016;31(8):564-572. doi:10.1177/0268355515597632
17. Yang S, Wang T, Long Y, Guo J, Hou Z. Risk factors of deep vein thrombosis in adults with acute compartment syndrome following lower extremity fractures. *Clin Appl Thromb Hemost*. 2023;29:10760296231165053. doi:10.1177/10760296231165053
18. Jayaraj A, Meissner MH. A comparison of Villalta-Prandoni scale and venous clinical severity score in the assessment of post thrombotic syndrome. *Ann Vasc Surg*. 2014;28(2):313-317. doi:10.1016/j.avsg.2012.11.014
19. Chen XL, Pan L, Wang Y. [Validity of Padua risk assessment scale for assessing the risk of deep venous thrombosis in hospitalized patients]. *Zhonghua Nei Ke Za Zhi*. 2018;57(7):514-517. doi:10.3760/cma.j.issn.0578-1426.2018.07.009
20. Autar R. Nursing assessment of clients at risk of deep vein thrombosis (DVT): the Autar DVT scale. *J Adv Nurs*. 1996;23(4):763-770. doi:10.1111/j.1365-2648.1996.tb00049.x
21. Zhang XQ, He D, Li JJ, Huang XB. [Validity of Caprini Risk Assessment Scale for Assessing Risk of Venous Thromboembolism in Hospitalized Critically Ill Patients]. *Sichuan Da Xue Xue Bao Yi Xue Ban*. 2015;46(5):732-735.
22. Peng G, Wang Q, Sun H, et al. Development and prospective validation of a novel risk score for predicting the risk of lower extremity deep vein thrombosis among multiple trauma patients. *Thromb Res*. 2021;201:116-122. doi:10.1016/j.thromres.2021.02.020

23. Lee JA, Zierler BK, Zierler RE. The risk factors and clinical outcomes of upper extremity deep vein thrombosis. *Vasc Endovascular Surg*. 2012;46(2):139-144. doi:10.1177/1538574411432145
24. Kawai T, Goto K, Kuroda Y, Matsuda S. Lower activity and function scores are associated with a higher risk of preoperative deep venous thrombosis in patients undergoing total hip arthroplasty. *J Clin Med*. 2020;9(5):1257. doi:10.3390/jcm9051257
25. Galanaud JP, Genty C, Sevestre MA, et al; OPTIMEV SFMV investigators. Predictive factors for concurrent deep-vein thrombosis and symptomatic venous thromboembolic recurrence in case of superficial venous thrombosis. The OPTIMEV study. *Thromb Haemost*. 2011;105(1):31-39. doi:10.1160/TH10-06-0406
26. Azboy I, Barrack R, Thomas AM, Haddad FS, Parvizi J. Aspirin and the prevention of venous thromboembolism following total joint arthroplasty: commonly asked questions. *Bone Joint J*. 2017;99-B(11):1420-1430. doi:10.1302/0301-620X.99B11.BJJ-2017-0337.R2
27. Iorio R, Schwartz B, Macaulay W, Teeney SM, Healy WL, York S. Surgical treatment of displaced femoral neck fractures in the elderly: a survey of the American Association of Hip and Knee Surgeons. *J Arthroplasty*. 2006;21(8):1124-1133. doi:10.1016/j.arth.2005.12.008
28. Wainwright TW, Gill M, McDonald DA, et al. Consensus statement for perioperative care in total hip replacement and total knee replacement surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations. *Acta Orthop*. 2020;91(1):3-19. doi:10.1080/17453674.2019.1683790
29. Whiting PS, White-Dzuro GA, Greenberg SE, et al. Risk factors for deep venous thrombosis following orthopaedic trauma surgery: an analysis of 56,000 patients. *Arch Trauma Res*. 2016;5(1):e32915. doi:10.5812/atr.32915
30. Yeoh CJ, Fazal MA. ASA grade and elderly patients with femoral neck fracture. *Geriatr Orthop Surg Rehabil*. 2014;5(4):195-199. doi:10.1177/2151458514560471
31. Wang JQ, Chen LY, Jiang BJ, Zhao YM. Development of a nomogram for predicting blood transfusion risk after hemiarthroplasty for femoral neck fractures in elderly patients. *Med Sci Monit*. 2020;26:e920255. doi:10.12659/MSM.920255
32. Tan Z, Hu H, Wang Z, Wang Y, Zhang Y. Prevalence and risk factors of preoperative deep venous thrombosis in closed patella fracture: a prospective cohort study. *J Orthop Surg Res*. 2021;16(1):404. doi:10.1186/s13018-021-02558-4
33. Cheng X, Fan L, Hao J, He H, Yan J, Zhu Y. Red cell distribution width-to-high-density lipoprotein cholesterol ratio (RHR): a promising novel predictor for preoperative deep vein thrombosis in geriatric patients with hip fracture. *Clin Interv Aging*. 2022;17:1319-1329. doi:10.2147/CIA.S375762
34. Johnson ED, Schell JC, Rodgers GM. The D-dimer assay. *Am J Hematol*. 2019;94(7):833-839. doi:10.1002/ajh.25482
35. Di Nisio M, Squizzato A, Rutjes AW, Büller HR, Zwinderman AH, Bossuyt PM. Diagnostic accuracy of D-dimer test for exclusion of venous thromboembolism: a systematic review. *J Thromb Haemost*. 2007;5(2):296-304. doi:10.1111/j.1538-7836.2007.02328.x
36. Alexander M, Burbury K. A systematic review of biomarkers for the prediction of thromboembolism in lung cancer - Results, practical issues and proposed strategies for future risk prediction models. *Thromb Res*. 2016;148:63-69. doi:10.1016/j.thromres.2016.10.020
37. Schouten HJ, Koek HL, Oudega R, et al. Validation of two age dependent D-dimer cut-off values for exclusion of deep vein thrombosis in suspected elderly patients in primary care: retrospective, cross sectional, diagnostic analysis. *BMJ*. 2012;344(jun06 1):e2985. doi:10.1136/bmj.e2985
38. Nybo M, Hvas AM. Age-adjusted D-dimer cut-off in the diagnostic strategy for deep vein thrombosis: a systematic review. *Scand J Clin Lab Invest*. 2017;77(8):568-573. doi:10.1080/00365513.2017.1390783