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Risk factors for deep vein thrombosis following total hip arthroplasty in elderly patients with femoral neck fractures during winter

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Abstract

Objective: To investigate the risk factors for deep vein thrombosis (DVT) following total hip arthroplasty in elderly patients with femoral neck fractures during the winter. **Methods:** A total of 162 patients who underwent total hip arthroplasty were categorized based on the development of DVT within 7 days postoperatively: 28 patients formed the DVT group and 134 patients the non-DVT group. Collected data included age, gender, history of glucocorticoid use, diabetes, hypertension, body mass index (BMI), triglyceride (TG) levels, cholesterol (CHOL) levels at admission, operative time, and postoperative bed rest duration. D-dimer (D-D) and fibrinogen (Fg) levels, along with the D-D/Fg ratio, were recorded on the first postoperative day. Group comparisons were performed using *t*-tests. Logistic regression analysis was conducted to identify independent risk factors, and the predictive value of these factors was evaluated using receiver operating characteristic (ROC) curve analysis. **Results:** In the DVT group, 18 patients had diabetes. Levels of TG (1.78 ± 0.44 mmol/L), CHOL (4.70 ± 1.84 mmol/L), D-D (0.40 ± 0.17 mg/L), and the D-D/Fg ratio (0.24 ± 0.07) were significantly higher than in the non-DVT group ($P < 0.05$). Logistic regression identified TG, CHOL, D-D, and the D-D/Fg ratio as independent risk factors for DVT, with odds ratios of 0.987, 2.395, 0.8, 4.992, and 9.004, respectively ($P < 0.05$). ROC curve analysis yielded areas under the curve (AUCs) of 0.715, 0.69, 0.614, and 0.726 for TG, CHOL, D-D, and the D-D/Fg ratio, respectively. Sensitivities were 0.643, 0.500, 0.429, and 0.857, and specificities were 0.694, 0.978, 0.918, and 0.537, respectively. **Conclusion:** Elevated levels of TG, CHOL, D-D, and the D-D/Fg ratio are independent risk factors for DVT following total hip arthroplasty in elderly patients. Among these, the D-D/Fg ratio demonstrated the highest sensitivity and may serve as an effective marker for early-stage DVT screening.

Keywords

deep venous thrombosis; total hip replacement; senile patients; risk factor; winter

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1 Introduction

Femoral neck fractures are the most common traumatic injury among the elderly and can result in severe disability. With an aging population, the annual number of cases is projected to rise steadily, reaching approximately 6.3 million to 8.2 million by 2050[1-2]. Only half of individuals who sustain a hip fracture regain their previous level of mobility and independence in daily activities, while 25% require institutional care. Mortality rates 5 years after a hip fracture are 20% higher than expected, with most deaths occurring within the first 6 months. Nearly all hip fractures are caused by falls, and many patients suffer recurrent falls shortly after the initial injury[3-4].

Numerous studies have examined the factors affecting the epidemiology of intracapsular hip fractures, frequently highlighting seasonal variations. Research has established a link between seasonal changes and the incidence of hip fractures[5]. Additionally, fluctuations in vitamin D and other hormones involved in bone metabolism have been observed with seasonal transitions. The decline in vitamin D levels during colder months, leading to elevated parathyroid hormone levels, is associated with

heightened bone resorption in winter, which likely impacts fracture healing[6]. Studies have reported a high incidence of femoral neck fractures caused by falls during winter[7]. This is particularly evident in northern China, where long winters lead to an increased number of femoral neck fractures among the elderly due to slips on icy roads, often necessitating total hip arthroplasty.

Research suggests that without anticoagulation, the incidence of lower limb deep vein thrombosis (DVT) following total hip arthroplasty ranges from 40% to 84%. DVT can lead to fatal pulmonary embolism, the leading cause of death following hip arthroplasty[8-9]. Falls are a significant risk factor for fragility fractures in the elderly, with studies indicating that 40% of individuals over 80 years old living in the community experience at least one fall annually, and 87% of these falls result in fractures[10]. As physiological functions decline with age, the perioperative adaptation and metabolism of elderly patients differ markedly from those of younger adults[11]. This study aims to identify risk factors associated with DVT formation after total hip arthroplasty in elderly patients, providing a theoretical basis for the early prevention of perioperative.

2 Materials and methods

2.1 General information

A total of 162 patients with femoral neck fractures who underwent total hip arthroplasty at the Second Affiliated Hospital of Harbin Medical University between May 2021 and May 2023 were included in this study. All patients received subcutaneous low molecular weight heparin injections or oral rivaroxaban for anticoagulation, following the Chinese Orthopaedic Surgery Guidelines for the Prevention of Venous Thromboembolism[12]. Color Doppler ultrasound examinations of the deep veins in both lower extremities were conducted 7 days postoperatively. Based on the presence or absence of thrombus formation, patients were divided into two groups: the DVT group (N = 28) and the non-DVT group (N = 134). Relevant perioperative risk factors for DVT formation were identified through a literature review (Table 1), and the correlations between these factors and DVT formation were retrospectively analyzed[13-17].

Inclusion criteria: (1) Age ≤ 60 years; (2) Diagnosis of femoral neck fracture; (3) Underwent unilateral total hip arthroplasty; (4) Primary hip replacement; (5) Written informed consent provided by patients or their legal representatives.

Exclusion criteria: (1) Preoperative use of oral anticoagulants or abnormal coagulation profiles; (2) Congenital hip joint dysplasia; (3) Preoperative deep vein thrombosis confirmed by Color Doppler ultrasound; (4) Active bleeding or thrombotic events within the past year.

This study was reviewed and approved by the hospital's ethics committee (Approval No. KY2024-156), and informed consent was obtained from all patients or their family members.

2.2 Treatment methods

Upon admission, general patient data were collected, including age, sex, history of hormone use, history of diabetes and hypertension, and body mass index (BMI), which was calculated as weight (in kilograms) divided by height (in meters) squared. Laboratory parameters recorded at admission included triglyceride (TG) levels, cholesterol (CHOL) levels. Additionally, operative time and postoperative bed rest duration were documented. Blood coagulation parameters, including plasma D-dimer (D-D) and fibrinogen (Fg) levels, were measured on the first postoperative day, and the D-D to fibrinogen ratio (D-D/Fg) was calculated.

2.3 Statistical methods

Continuous variables were expressed as mean ± standard deviation, and comparisons between groups were conducted using independent samples t-tests. Categorical variables were presented as case numbers, with comparisons performed using the χ^2 test. A t-test was used to assess differences between the DVT and non-DVT groups. Logistic regression analysis was performed to identify independent risk factors for DVT formation. The predictive power of these factors was further evaluated using ROC) curve analysis. Multivariate logistic regression analysis was employed to identify independent risk factors for DVT. The area under the ROC curve (AUC) was calculated using MedCalc 15.1 statistical software, and group comparisons of AUCs were conducted using the z-test. A two-sided P-value of < 0.05 was considered statistically significant.

3 Results

3.1 Comparison of general data of patients

A comparison of general data between the two patient groups is presented in Table 1. No significant differences were observed in age, gender, operation time, postoperative bed rest duration, history of hormone use, history of hypertension, BMI, or Fg levels. However, significant differences were noted in diabetes history, serum TG and CHOL levels, plasma D-D, and the D-D/Fg ratio. Therefore, diabetes history, TG, CHOL, D-D, and the D-D/Fg ratio were included as variable s in the logistic regression analysis to identify potential risk factors.

3.2 Screening of risk factors for postoperative DVT

The results of risk factor screening for postoperative DVT are presented in Table 2. Logistic regression analysis revealed that the correlation coefficients (B) for diabetes history, TG, CHOL,

Table 1 Comparison of general data between two groups of patients

Influencing factors	DVT (*N* = 28)	Without DVT (*N* = 134)	t/χ^2	*P*
Age	69.4 ± 7.9	71.0 ± 7.4	1.00	0.316
Gender				
Male	16	71	0.16	0.688
Female	12	63		
Operation time (h)	1.62 ± 0.36	1.54 ± 0.38	1.02	0.312
Postoperative bed rest time (h)	25.3 ± 5.7	24.3 ± 6.6	2.00	0.842
Hormone use				
Yes	9	22	3.70	0.054
No	19	112		
Diabetes				
Yes	18	56	4.72	0.030
No	10	78		
Hypertension				
Yes	6	32	0.08	0.781
No	22	102		
TG (mmol/L)	1.78 ± 0.44	1.49 ± 0.34	3.35	0.002
CHOL (mmol/L)	4.70 ± 1.84	3.63 ± 0.96	2.99	0.006
BMI	25.4 ± 4.6	24.3 ± 6.6	0.81	0.421
D-D (mg/L)	0.40 ± 0.17	0.33 ± 0.10	2.15	0.039
Fg (g/L)	1.84 ± 1.06	2.54 ± 2.23	1.63	0.106
D-D/Fg	0.24 ± 0.07	0.18 ± 0.09	3.68	<0.001

DVT, deep vein thrombosis; TG, triglyceride; CHOL, cholesterol; BMI, body fat number; D-D, D-dimer; Fg, fibrinogen.

D-D, and D-D/Fg with postoperative DVT were 0.987, 2.395, 0.8, 4.992, and 9.004, respectively. The Wald χ^2 test indicated that diabetes history ($P > 0.05$) was not an independent risk factor for DVT, whereas TG, CHOL, D-D, and the -D/Fg ratio ($P < 0.05$) were identified as independent risk factors for DVT following total hip arthroplasty.

3.3 Analysis of diagnostic value of independent risk factors

The ROC curve illustrating the diagnostic value of the four independent risk factors are shown in Fig. 1, with the corresponding ROC curve analysis presented in Table 3. The AUC for TG, CHOL, D-D, and the D-D/Fg ratio were 0.715, 0.69, 0.614, and 0.726, respectively. The diagnostic cutoff values for each index, determined by the Youden index, were 1.61, 5.32, 0.47, and 0.185, respectively, along with their corresponding sensitivity and specificity. A comparison of AUCs among the groups revealed no significant differences ($P > 0.05$), suggesting that the predictive abilities of the four indices for DVT formation were comparable.

4 Discussion

DVT is a common complication following total hip arthroplasty, often with an insidious onset that is difficult to detect early. Some patients may present with swelling of the affected limb. Emboli formed from thrombi can obstruct the pulmonary artery via venous blood flow, leading to potentially fatal pulmonary embolism (PE), which has become the leading cause of death after joint replacement surgery[18-19]. As such, preventing DVT remains a significant challenge for joint surgeons worldwide. Recent studies, both domestic and international, have shown that poor lifestyle habits, underlying health conditions, and iatrogenic factors are closely linked to the development of postoperative DVT[20-21]. Drawing from literature reviews and clinical experience, this study aimed to identify and evaluate indicators potentially associated with DVT formation to explore the risk factors for perioperative DVT in elderly patients undergoing total hip arthroplasty, ultimately providing a foundation for effective DVT prevention strategies.

Compared to younger adults, elderly patients face several unfavorable factors, including decreased physical function, weakened immunity, multimorbidity, and a higher incidence of osteoporosis. These factors contribute to a greater risk of complications after hip arthroplasty, with the perioperative period often marked by prolonged surgery and extended bed rest, creating conditions conducive to DVT formation. Therefore, early prevention, identification, and treatment of DVT in elderly patients are particularly crucial[22]. The gold standard for diagnosing DVT is lower limb angiography[23]; however, due to its high cost, invasiveness, and the

Table 2 Screening of risk factors for postoperative DVT

Predictive indicators	*B*	*S.E.*	*Wald*	*P*	*OR*	*95%CI*
diabetes	0.987	0.547	3.258	0.071	2.683	0.919-7.834
TG	2.395	0.726	10.889	0.001	10.968	2.644-45.489
CHOL	0.800	0.213	14.103	0	2.226	1.466-3.381
D-D	4.992	2.111	5.593	0.018	147.232	2.351-9221.482
D-D/Fg	9.044	3.249	7.750	0.005	8465.607	14.534-4.93×10^6

TG, triglyceride; CHOL, cholesterol; D-D, D-dimer; Fg, fibrinogen.

Table 3 Parameters of ROC curves of risk factors for DVT

Predictive indicators	AUC	*S.E.*	*P*	*95%CI*	Boundary value	sensitivity	Specificity degree
TG	0.715	0.056	0	0.605-0.826	1.61	0.643	0.694
CHOL	0.690	0.071	0.002	0.550-0.829	5.32	0.500	0.978
D-D	0.614	0.071	0.058	0.474-0.754	0.47	0.429	0.918
D-D/Fg	0.726	0.048	0.000	0.633-0.820	0.185	0.857	0.537

TG, triglyceride; CHOL, cholesterol; D-D, D-dimer; Fg, fibrinogen.

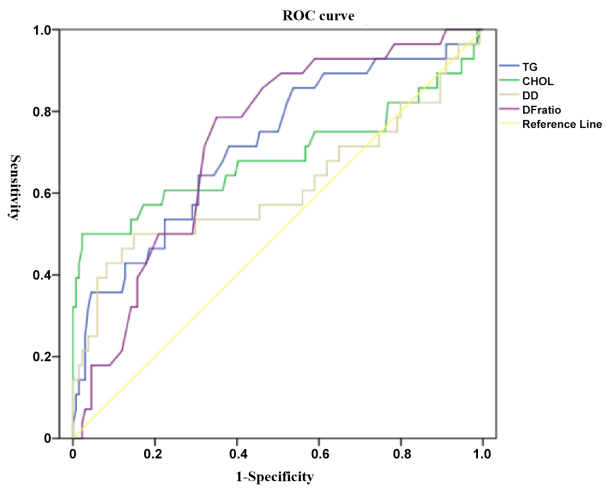

Fig. 1 ROC curve of risk factors for DVT

ROC, receiver operating characteristic; DVT, deep vein thrombosis.

potential risk for causing prosthetic infection post-hip arthroplasty, its clinical application is limited. Currently, color Doppler ultrasound is frequently used to examine the deep veins of the lower extremities. This method is less invasive, highly accurate, and cost-effective, although the results can be significantly influenced by the operator's skill level. To minimize this bias, two senior ultrasound specialists conducted the examinations in this study. Among the 162 samples, 28 cases developed DVT, resulting in an incidence rate of 17.2%. Four cases presented with limb swelling, while the remainder were asymptomatic DVT cases, and no cases of PE or mortality were reported.

In this study, the collected indicators were analyzed using an independent samples t-test to identify differences between the two groups. Patients in the DVT group had higher levels of TG, CHOL, D-D, and D-D/Fg, as well as a higher prevalence of diabetes, compared to the non-DVT group. These variables were included as risk factors in the logistic regression analysis. The analysis revealed that diabetes had little association with the occurrence of DVT and was not an independent risk factor for DVT formation, which contrasts with findings from studies encompassing all age groups[24]. This discrepancy might be due to the higher prevalence of type 2 diabetes among the elderly and the varying degrees of blood glucose control. TG, CHOL, D-D, and D-D/Fg were identified as independent risk factors for DVT after hip arthroplasty. ROC curve analysis showed that the AUCs were 0.715, 0.69, 0.614, and 0.726, respectively. MedCalc software analysis indicated no significant difference in AUCs between these variables ($P > 0.05$), suggesting that all four indices have similar diagnostic abilities for DVT. However, TG demonstrated a more balanced sensitivity and specificity, while CHOL and D-D had higher specificity but lower sensitivity, leading to a higher risk of false negatives. On the other hand, D-D/Fg showed high sensitivity but lower specificity, resulting in a higher risk of false positives. Given the serious consequences of DVT, a sensitive index like D-D/Fg should be prioritized in clinical screening. The cutoff value for D-D/Fg, determined by the Youden index, is 0.185. Therefore, special attention should be given to patients with a postoperative D-D/Fg higher than 0.185, as they have a significantly increased risk of developing DVT. Early intervention, such as the use of ankle pumps to improve lower extremity circulation or adjustment of anticoagulant dosage, should be considered.

D-D is a specific product formed during the degradation of cross-linked fibrinogen and is known for its stability. An increase in D-D indicates the physiological processes of thrombosis and secondary fibrinolysis within the body[25]. In

surgical patients, D-D levels often rise postoperatively due to factors such as incision bleeding and coagulation, making it challenging to assess DVT formation based solely on D-D levels. Fg, also known as coagulation factor 1, plays a crucial role in blood coagulation by forming fibrin monomers under the action of thrombin, which then polymerize to form cross-linked fibrin[26]. However, the findings of this study suggest that there is no significant correlation between elevated Fg levels and DVT formation after total hip arthroplasty. Recent studies have shown that the ratio of D-D to Fg holds diagnostic value for DVT formation[27]. The results of this study align with these findings, although the D-D/Fg ratio demonstrated high sensitivity but low specificity, potentially increasing the rate of misdiagnosis. Additionally, due to the sample size and other related factors, the 95% confidence interval for the D-D and D-D/Fg ratios in this study were relatively broad, indicating the need for further research with an improved model.

This study has several limitations. First, it was conducted in a single center, lacking multi-center data support. There may be regional and hospital-specific factors limiting the external validity of the results. Second, although a variety of variables were considered, there may still be uncontrolled confounding factors, such as patients' living habits and postoperative rehabilitation measures, which could affect the accuracy of the results.

5 Conclusion

In summary, TG, CHOL, D-D, and D-D/Fg were identified as independent risk factors for the development of DVT following total hip arthroplasty in elderly patients. Among these, the D-D/Fg ratio demonstrated the highest sensitivity and may serve as an effective index for the early detection and prevention of DVT.

Acknowledgement

Not applicable.

Research ethics

This study was approved by the Institutional Ethics Committee of the Second Affiliated Hospital of Harbin Medical University (KY2024-156).

Informed consent

Informed consent was obtained from all patients or their family members.

Author contributions

All authors contributed substantially to this work through study conception and design, data acquisition, analysis, and interpretation. Each author was involved in drafting the manuscript, revising it critically for important intellectual content, and providing final approval of the version to be published. All authors agree on the submission and assume full responsibility for the accuracy and integrity of the work.

Use of large language models, AI and machine learning tools

No LLM, AI or machine learning tool was used for any part of thepresent study.

Conflict of interest

The authors have not identified any potential conflicts of interest.

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Data availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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