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Incidence of deep venous thrombosis following medial opening-wedge high tibial osteotomy for varus knee osteoarthritis: a retrospective study

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Abstract

Purpose Deep venous thrombosis (DVT) is a common yet underexplored complication following medial opening-wedge high tibial osteotomy (MOWHTO) for medial compartment knee osteoarthritis. Existing studies report inconsistent findings due to methodological differences and patient heterogeneity. This study aims to determine the incidence and risk factors for DVT after MOWHTO.

Methods We retrospectively reviewed patients who underwent MOWHTO for medial compartment knee osteoarthritis with varus deformity between January 2019 and September 2023. Patients were classified into DVT and non-DVT groups based on Doppler ultrasonography findings. Univariate analysis was performed to compare demographics, lifestyle factors, comorbidities, surgical details, and laboratory results on postoperative day 1 between the DVT and non-DVT groups. Receiver operating characteristic (ROC) curve and area under the curve (AUC) were used to evaluate the predictive performance of laboratory indices for DVT. Multivariate logistic regression model identified independent risk factors for DVT.

Results Of the 421 patients (median age: 56 years, interquartile range: 52–61 years; 146 males), 55 (13.1%) developed postoperative DVT. The incidence rates for isolated calf muscle vein thrombosis (ICMVT), deep calf vein thrombosis (DCVT), and proximal DVT was 10.7%, 1.9% and 0.5%, respectively. Most laboratory indexes demonstrated non-significant ($P > 0.05$) or poor (AUC < 0.70) predictive performance, except for AT III and FDP ($p = 0.022$, 0.033, respectively). The multivariate logistic regression analyses showed female (OR, 2.23; 95% CI, 1.09 to 4.63), diabetes (OR, 2.47; 95% CI, 1.15 to 5.40) and hyperlipidemia (OR, 1.91; 95% CI, 1.14 to 3.68) were significantly associated with postoperative DVT.

Conclusion This study identified a high incidence of DVT following MOWHTO and demonstrated that female sex, diabetes and hyperlipidemia were significant risk factors. These findings may inform better risk assessment, stratification and management of DVT.

Clinical trial number Not applicable.

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Keywords Knee osteoarthritis, MOWHTO procedure, Deep venous thrombosis, Risk factors, Prevention

Introduction

Medial opening-wedge high tibial osteotomy (MOWHTO) is a well-established and widely performed procedure for treating medial compartment knee osteoarthritis with varus deformity, particularly in younger, active patients [1]. However, due to the inherent surgical invasiveness, the risk of postoperative deep venous thrombosis (DVT) remains significant, even with standard chemoprophylaxis [2, 3]. DVT can result in severe complications including fatal pulmonary embolism [4], and may adversely affect patient outcomes if left undiagnosed or untreated [5]. Therefore, a comprehensive understanding of its incidence, anatomical distribution, predictive laboratory markers, and associated risk factors is crucial for improving preventive strategies.

A review of the existing literature reveals a scarcity of data on postoperative DVT specifically related to MOWHTO, with reported incidence rates ranging from 2.4 to 41% [2, 3, 6–8], mainly due to differences in institutional practices, prophylaxis protocols, detection methods, patient populations, and study designs. For instance, regarding the effectiveness of chemoprophylaxis prophylaxis in an Asian population undergoing total knee arthroplasty, Kim et al. [3] reported a lower DVT rate in the chemoprophylaxis group compared to the control group (10.6% vs. 14.9%), although the difference was not statistically significant. However, the small sample size (66 in the chemoprophylaxis group and 67 in the control group) may have hindered the power to detect a true effect. Similarly, studies investigating the risk factors for DVT have reported inconclusive or conflicting results [2, 9] or have limited applicability due to the inclusion of preoperative DVT cases [9]. To address this gap, in 2023, our research team developed a nomogram model based on data from patients treated from June 2017 to December 2021. This model identified several key risk factors for DVT after MOWHTO, including higher Kellgren–Lawrence (K–L) grade, platelet to hemoglobin ratio > 2.25, low albumin level, LDL-C levels > 3.40 mmol/L, D-dimer above 1.26 mg/L and BMI ≥ 28 kg/m^2 [10]. More recently, we expanded on this research by introducing a novel predictor, the low-density lipoprotein cholesterol-to-lymphocyte count ratio, which further improved risk stratification in this population [11].

This study extends the research period through September 2023 to gain a deeper understanding of the incidence and risk factors for postoperative DVT among MOWHTO patients. Using a retrospective cohort design, we systematically collected clinical data and mandatory postoperative ultrasonographic imaging results. Our objectives are to determine the incidence of new episodes of DVT following MOWHTO, evaluate the predictive utility of routine laboratory markers, and identify independent risk factors for DVT occurrence.

Methods

Data resource and inclusion and exclusion criteria

This is a retrospective, single-center study. Between January 2019 and September 2023, a consecutive cohort of 569 patients who underwent MOWHTO with medial locking plate fixation to treat medial compartment knee osteoarthritis with varus deformity were screened for inclusion. The exclusion criteria included a history of venous thromboembolism (VTE), congenital or acquired bleeding disorders (e.g., hemophilia) documented in medical records, anticoagulation and/or antiplatelet therapy within 3 months before admission, undergoing bilateral knee osteotomies in one stage or concomitant ligament reconstruction, osteotomies other than MOWHTO, preoperatively documented VTE, malignancy or incomplete data.

The study protocol was approved by the Ethics Committee of the Hebei Medical University Third Hospital before study initiation. The committee waived the requirement for informed consent, as the data were de-identified, the study posed no direct risk to participants, and obtaining individual consent was deemed impractical due to the retrospective nature of the research. This study was carried in accordance with the Helsinki Declaration.

Detection and management of DVT

DVT was diagnosed in accordance with the guideline for diagnosis and treatment of DVT updated by the Chinese Medical Association [12]. Screening and confirmation of postoperative DVT was performed using ultrasonography by experienced board-certified sonographers under a standardized protocol. According to institutional policy, mandatory ultrasonographic screening for preoperative and postoperative lower extremity DVT was performed after admission (generally at day 1) and before discharge (generally at day 3 to 7 postoperatively based on anticipated discharge time [13]) using Doppler ultrasonography, color Doppler and compression technique. DVT was classified into three categories: proximal DVT, involving popliteal veins or proximal (iliac, superficial femoral, deep femoral, common femoral veins); isolated calf muscle vein thrombosis (ICMVT), involving gastrocnemius and/or soleal vein; and distal calf vein thrombosis (DCVT), involving peroneal, anterior tibial, or posterior tibial veins.

For patients who were found to have preoperative DVTs, administration of a therapeutic dose of

anticoagulant (e.g., Low molecular weight heparin (LMWH), 4000-6000iu on basis of weight (kg), subcutaneous injection twice a day) until surgery or inferior vena cava filter placement (for proximal DVT or unstable DVTs) was performed. For patients who were found to have no DVT, prophylactic dose of LMWH (4000-6000iu on basis of weight in kg, once a day) was administered postoperatively for one week. For patients who developed DVT postoperatively, therapeutic dose of anticoagulant (e.g., Low molecular weight heparin (LMWH), 4000-6000iu on basis of weight in kg, subcutaneous injection twice a day), was administration for 7 to 14 days, typically. And for some cases at higher risk of DVT recurrence (e.g., obesity, previous DVT, extended immobility after surgery), up to 4 weeks will be recommended. Post-discharge, patients will transition to oral anticoagulants such as warfarin or direct oral anticoagulants (DOACs).

MOWHTO procedure and postoperative management

The MOWHTO procedure was performed in accordance with the biplanar osteotomy technique with medial locking plate fixation proposed by Lovenhoffer et al. [14]. Before surgery, surgical planning and radiographic evaluation were conducted based on full-length lower limb weight-bearing radiograph in anteroposterior view to determine the correction angle. General anesthesia with peripheral nerve block and a pneumatic tourniquet were applied for all patients. Generally, prior to osteotomy, arthroscopic examination and procedures for meniscal and/or chondral lesions (irrigation of debris, partial meniscectomy of degenerative tears) were performed as needed. Prophylactic antibiotic (cefazolin 1.0 g, or vancomycin 1.0 g in cases of allergy) was administered 30 to 60 min prior to skin incision. Osteotomy was performed in biplanar manner at an angle of 120° on both osteotomy planes [15]. Under the fluoroscopic control, the preoperatively predetermined osteotomy gap and alignment were obtained, followed by stabilization with a medial T-shaped locking plate (Wego TM, Weihai, China). For cases with larger posterior opening wedge (i.e., > 10 mm), autogenous or allogeneic bone graft, or artificial repair material, was filled in the medial osteotomy gap to facilitate healing. A drainage tube was applied for all patients and removed on day 2 postoperatively. All procedures were completed by the surgeons with at least 10 years of experience. Each surgeon performed a median of 26 MOWHTO procedures (interquartile range [IQR], 18 to 37) during the study period.

Postoperatively, bilateral compression stockings and/or mechanical compression devices were applied immediately after surgery in all patients. Isometric quadriceps and active ankle exercises were initiated after surgery without immobilization. Non-weight-bearing mobilization on crutches was initiated on postoperative day 2 and continued for the first 4 weeks. Partial weight-bearing was introduced between weeks 5 and 6, followed by full weight-bearing thereafter.

Variables of interest

Two authors collected the relevant data from medical records and laboratory testing reports. These data included demographics (age and sex), lifestyle habits (smoking and alcohol consumption), comorbidities (obesity defined as body mass index (BMI) ≥ 28 kg/m^2, hypertension, diabetes, cardiovascular disease, pulmonary disease, hepatobiliary disease, hypercholesterolemia, hyperlipidemia, past history of lower extremity surgery), osteoarthritis conditions (affected side, preoperative radiographic Kellgren–Lawrence grade), surgical details (time to operation, American Society of Anesthesiologists (ASA) grade, surgical duration, intraoperative blood loss, size of osteotomy), and laboratory markers on postoperative day 1 (serum albumin, red blood cell (RBC) count, hemoglobin, hematocrit, white blood cell (WBC) count, neutrophils, lymphocytes, platelets, fasting blood glucose (FBG), sodium concentration, fibrinogen, international normalized ratio (INR), activated partial thromboplastin time (APTT), APTT ratio, thrombin time (TT), thrombin time ratio (TT-R), fibrinogen degradation products (FDP), and antithrombin III (AT III).

Statistical analysis

The normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed data were compared using the Student's t-test, and non-normally distributed data were analyzed with the Mann-Whitney U test. For categorical variables, the Chi-square test or Fisher's exact test was applied, depending on the data characteristics.

To evaluate the predictive ability of laboratory indexes for postoperative DVT, receiver operating characteristic (ROC) curve was used and the area under the curve (AUC) was calculated to quantify the ability. If a statistically significant ability was confirmed for a variable, the optimal cut-off value was determined by maximizing the AUC [16]. Dichotomization was then performed, followed by uni-and multivariate analyses as necessary.

To examine the potential independent effect of variables on DVT, multivariate logistic regression analysis was performed, adjusting for variables with $P < 0.10$ in univariate analyses. The stepwise backward method was used, and variables with $P < 0.10$ were retained in the final model. The goodness-of-fit of the final model was evaluated using the Hosmer-Lemeshow test, and the result was quantified by the adjusted Nagelkerke R^2 value, with $P > 0.05$ and $R^2 < 0.750$ considered as acceptable [17]. The magnitude of association with DVT was indicated by odds ratio (OR) with a 95% confidential interval (95% CI).

The statistical significance level was set as $P < 0.05$, and all analyses were performed using SPSS 26.0 (IBM corporation, New York, USA).

Results

After stringent screening (flowchart in Fig. 1), 421 patients were included, with 146 males and 275 females, with a median age of 56 years (interquartile range (IQR, 52 to 61 years)). The median time from admission to surgery was 2 days (IQR, 2 to 3 days). The median length of incision for the procedure was 7 cm (IQR, 6 to 8 cm), and in 80.3% of patients, the surgical duration was less than 120 min (338, 80.3%).

Postoperatively, 55 patients (13.1%) developed a new DVT at a median of 6 days (interquartile range, 4 to 7 days). Based on the location of the thrombi, 45 (81.8%; incidence, 10.7%) were IMCVT, followed by DVCT (8, incidence, 1.9%). Only 2 cases (0.5%) were proximal DVT, occurring in the popliteal vein or common femoral vein, respectively. Among the 55 patients with DVT, 41 had DVT on the operative side, 9 on the contralateral non-operative side, and 5 cases were bilaterally. All DVT cases were asymptomatic. One case of pulmonary embolism was found, with a concomitant IMCVT.

Figure 2 shows the ROC curves for DVT and biomarkers. Most laboratory markers demonstrated no predictive or diagnostic ability for DVT, except for AT III and FDP, which were tested with $P = 0.032$ and 0.022 respectively. However, both markers had poor ability (AUC, 0.612 for AT III, and 0.604 for FDP respectively) according to a previously described grading method [18], with corresponding optimal cut-off values of 100.0% and 1.37 mg/L, respectively (Table 1). As for D-dimer, the most commonly used index for initial DVT screening, the AUC was 0.525 with no diagnostic ability, and no statistical significance was found ($P = 0.609$) (Table 1.

There were significant differences between the DVT and non-DVT groups in terms of sex (male, 21.8% vs. 36.6%, $P = 0.032$), prevalence of diabetes (20.0% vs. 9.3%, $P = 0.017$), pulmonary disease (14.5% vs. 6.3%, $P = 0.029$), and hyperlipidemia (43.6% vs. 28.1%, $P = 0.020$) (Table 2). The DVT group showed a trend towards higher prevalence of hypercholesterolemia (43.6% vs. 30.9%), with marginal significance ($P = 0.060$). (Table 2)

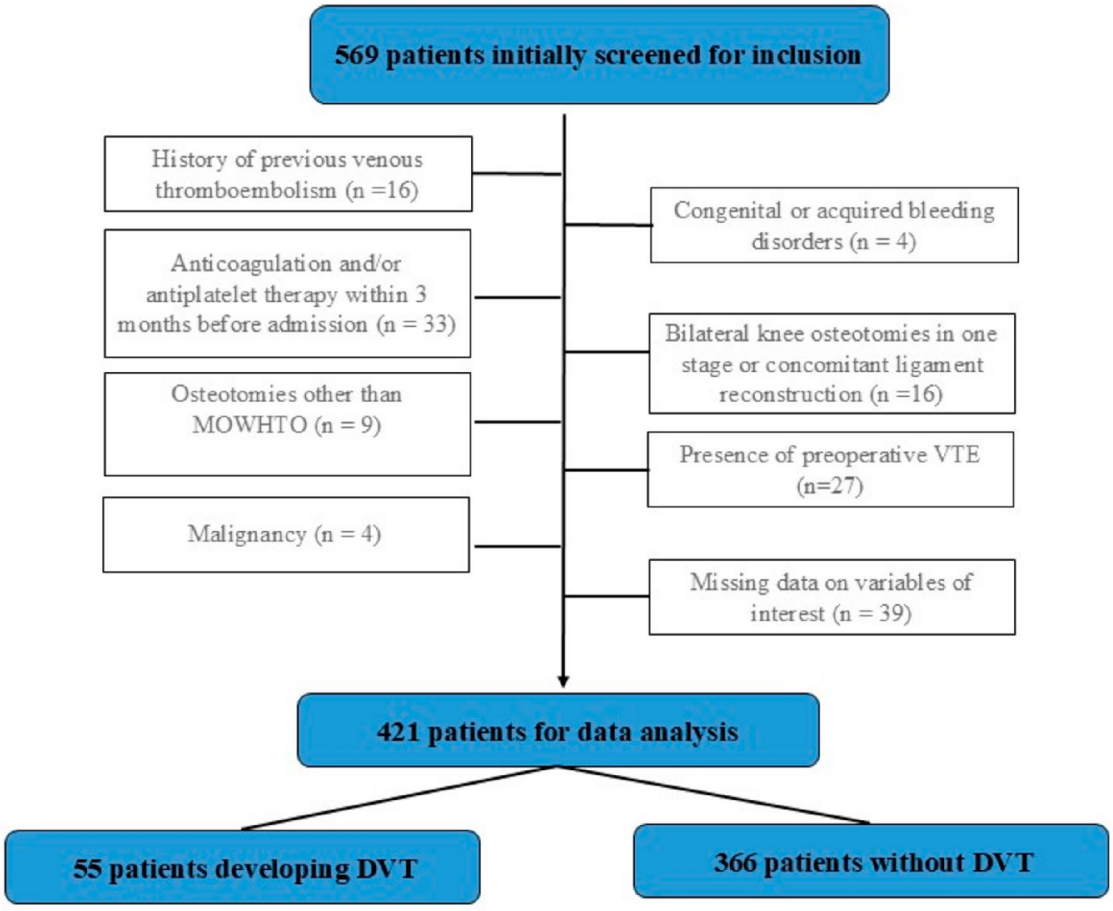

Fig. 1 Flow diagram of patient screening and selection

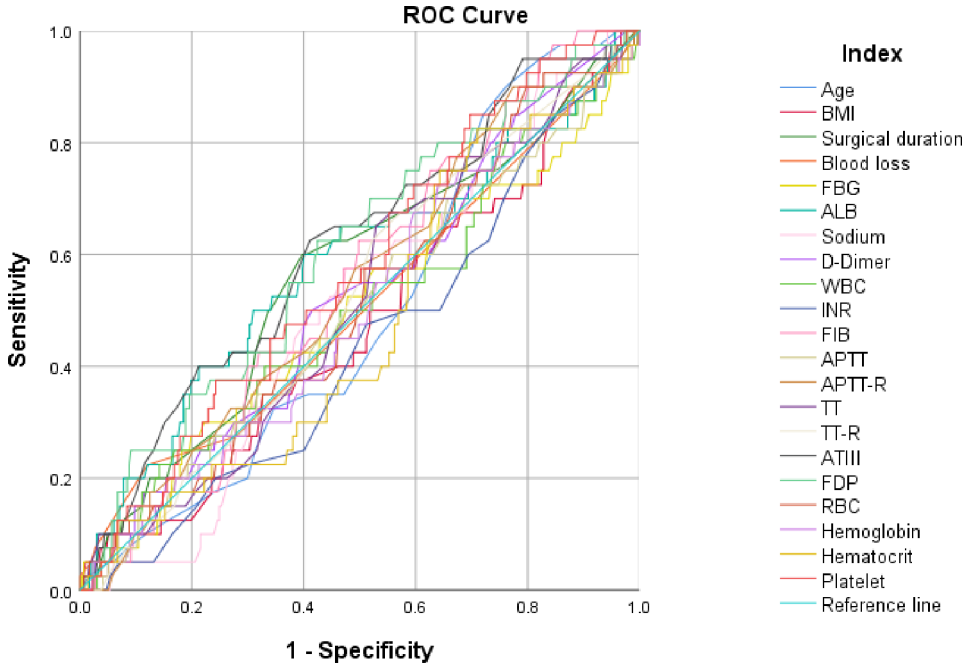

Fig. 2 The ROC curve and AUC for a variety of continuous variables. Most laboratory indexes demonstrated no predictive or diagnostic ability for DVT, except for AT III and FDP, with $P = 0.032$ and 0.022 respectively, but both have poor ability (AUC, 0.612 for AT III, and 0.604 for FDP)

In the multivariate model, female sex (OR, 2.23; 95% CI, 1.09 to 4.63; $P = 0.021$), diabetes (OR, 2.47; 95% CI, 1.15 to 5.40; $P = 0.014$) and hyperlipidemia (OR, 1.91; 95% CI, 1.14 to 3.68; $P = 0.029$) remained significant. The results were presented in Table 3. The Hosmer-Lemeshow test showed acceptable goodness-of-fit of the final model ($P = 0.374$, adjusted Nagelkerke $R^2 = 0.446$).

Discussion

Data on the characteristics of postoperative DVT following MOWHTO for treating varus KOA remains scarce. In this study, we focused on a cohort routinely administered chemoprophylaxis and found a high incidence rate of postoperative DVT (13.1%), with 10.7%, 1.9% and 0.5% for ICMVT, DCVT and proximal DVT, respectively. The laboratory markers in this study showed no or poor predictive or diagnostic ability. Three risk factors were identified, including female sex, diabetes and hyperlipidemia.

Studies examining the incidence of DVT following MOWHTO reported the greatly variable results, primarily due to the differences in the modalities for detecting DVT, prophylactic measures, and the study designs [1, 3, 19]. Onishi et al. [2] reported a similar DVT rate of 13.8% with routine prophylaxis using edoxaban (15 mg per day until 1 week after operation), as assessed by ultrasonography at postoperative day 7. In another study examining the need for chemoprophylaxis (2.5 mg fondaparinux for 5 days postoperatively) to prevent DVT, Kim et al. [3] demonstrated the non-significant DVT rate between the chemoprophylaxis group (10.6%) and the control group (14.9%). However, this lack of significance was likely due to the small sample size ($n = 66$ and 67, respectively) and the study's primary focus not being on DVT incidence. It should be noted that all of the three studies (including the present one) reporting comparable lower DVT rates than Westerns were conducted in East Asian countries, which may reflect ethnicity differences, a low obesity prevalence rate and a low fat dietary pattern [20, 21].

In our study, over 80% of the thrombi in DVT cases were located in the calf muscle veins (gastrocnemius and/or soleal veins). The clinical significance of ICMVT, particularly its potential for proximal propagation and risk of pulmonary embolism, remains controversial [22–24]. Some studies suggest that ICMVT carries a low risk of complications and can be managed conservatively with serial imaging and regular follow-up, others report a non-negligible risk of thrombus extension and PE, advocating for active treatment with anticoagulation together with compression therapy [25]. Due to the inconsistent and variability in previous literature, it is difficult to make evidence-based recommendations regarding the clinical importance and optimal treatment regimen for ICMVT. Therefore, we recommend a tailored approach to managing ICMVT, taking into account individual patient risk factors. For patients with a higher risk of thrombus extension or PE, early initiation of anticoagulation may be warranted; in contrast, for low-risk patients, close monitoring with serial ultrasonography may be a reasonable alternative. Only 2 cases of proximal DVT were found, representing a very low rate (0.5%),

Table 1 The ROC analysis and the AUC results for continuous variables

Variables	AUC	Standard error	*P* value	Lower limit of 95%CI	Upper lower of 95%CI
Age	0.497	0.043	0.946	0.413	0.581
BMI	0.474	0.049	0.598	0.379	0.570
Surgical duration	0.565	0.050	0.181	0.467	0.663
Intraoperative blood loss	0.510	0.052	0.843	0.408	0.611
FBG	0.497	0.052	0.953	0.395	0.599
Albumin	0.581	0.052	0.096	0.478	0.684
Sodium concentration	0.506	0.044	0.908	0.419	0.592
D-Dimer	0.525	0.047	0.609	0.432	0.618
WBC	0.502	0.051	0.968	0.401	0.603
INR	0.437	0.046	0.195	0.346	0.528
Fibrinogen	0.550	0.043	0.302	0.465	0.635
APTT	0.500	0.049	0.994	0.403	0.597
APTT-R	0.540	0.047	0.413	0.448	0.631
TT	0.516	0.047	0.748	0.424	0.607
TT-R	0.524	0.046	0.628	0.433	0.614
AT III	0.612	0.047	0.022[#]	0.519	0.705
FDP	0.604	0.047	0.033[#]	0.511	0.697
RBC	0.512	0.047	0.806	0.420	0.604
Hemoglobin	0.501	0.048	0.983	0.406	0.596
Hematocrit	0.477	0.047	0.631	0.385	0.568
Platelet	0.575	0.045	0.123	0.487	0.664

[#]Significant variable

Abbreviates: ROC, receiver operating characteristic; AUC, area under the curve; CI, confidence interval; BMI, body mass index; FBG, fasting blood glucose; RBC, red blood cell; WBC, white blood cell; INR, International Normalized Ratio; APTT, activated partial thromboplastin time; APTT-R, activated partial thromboplastin time ratio; AT III, antithrombin III; FDP, Fibrinogen Degradation Products; TT, thrombin time; TT-R, thrombin time ratio

which is consistent with findings from Onishi et al. and Kim et al. (incidence of 0.6% and 0.7, respectively) [2, 3]. Future prospective studies with larger sample sizes are warranted to determine whether routine chemoprophylaxis is needed in a baseline population of patients, specifically evaluating the benefits (reduction of DVT) and risks (bleeding events, such as ecchymosis, hematoma or blood loss requiring transfusion).

D-dimer is the most extensively used index for initial DVT screening in a variety of medical settings; however, in this study, the D-dimer level measured on postoperative day 1 demonstrated no distinguishing ability. This finding is consistent with Onishi et al.' [2] study, where D-dimer level was not significantly different between DVT and non-DVT groups, either preoperatively ($p = 0.440$) or 1 week postoperatively ($P = 0.390$). Similar results were observed in other studies on elective total knee arthroplasty, with some authors attributing this to the decreased thrombus volume and size caused by routine chemoprophylaxis [26]. Coagulation indexes in our study also showed no or very poor predictive or diagnostic ability. Thus, for the MOWHTO procedure, routine blood parameters may provide limited clinical value in predicting or initially screening for postoperative DVT. Future research could explore more specific indexes, such as those related to from immunity or inflammation [11].

This study identified female sex, diabetes and hyperlipidemia as independent risk factors for DVT, all of which have been discussed in other orthopaedic procedures [27, 28] but have not been specifically reported for MOHTO. Female sex as a risk factor for DVT may be related to estrogen level, which positively regulate platelet activity and the subsequent clotting cascade [29], particularly when combined with other risk factors (e.g., surgical procedure herein). Additionally, estrogen affects blood rheology by increasing blood viscosity and promoting endothelial dysfunction, both of which predispose to thrombosis [30]. Diabetes, particularly in the context of hyperglycemia, is associated with blood hypercoagulability, vascular endothelial damage, and reduced fibrinolysis, all of which facilitate the occurrence of DVT. This finding is consistent with previous studies, including one that reported a 2.7-fold increase in the risk of DVT in diabetic patients undergoing total knee arthroplasty compared with non-diabetic patients [31]. This underscores the significant impact of diabetes on DVT risk and suggests that clinicians should clinicians should maintain heightened vigilance when managing DVT risk in diabetic patients undergoing MOWHTO. Specifically, it may be prudent to consider more aggressive thromboprophylaxis strategies and to closely monitor these patients for early signs of DVT during the postoperative phase.

Similarly, hyperlipidemia contributes to vascular endothelial damage, vascular lumen stenosis, and intimal damage, all of which impair the vessel's ability to regulate normal coagulation and fibrinolysis [32]. The presence of atherosclerotic plaques increases the risk of both arterial and venous thromboembolism. In practice, patients involving these factors should be considered as high-risk group to target for thromboprophylaxis, and these factors can also be used as a basis for developing future risk prediction model.

These findings have several important implications for real-world clinical practice. First, the high to 13.1% incidence of postoperative DVT suggests that the current prophylactic measures may not be fully effective in preventing DVT, particularly in high-risk populations. This underscores the need for individualized prophylactic strategies, which may include additional or alternative approaches. Second, the limited predictive value of the laboratory indices evaluated highlights the importance of integrating clinical assessments, patient-specific characteristics, and novel derived indices (e.g., low-density lipoprotein cholesterol-to-lymphocyte count ratio) [11]. The three risk factors identified in this study suggest patients with these characteristics may benefit from

Table 2 Univariate analysis of variables between DVT and non-DVT group

Variables	DVT group ($n=55$)	Non-Group ($n=366$)	*P*
Sex			0.032
Male	12 (21.8)	134 (36.6)	
Female	43 (78.2)	232 (63.4)	
Age (year)	57.3 ± 5.8	56.1 ± 6.5	0.192
≥60	19	112	0.556
<60	36	254	
BMI (kg/m^2)	26.4 ± 3.4	26.7 ± 3.4	0.489
<28	42 (76.4)	241 (65.8)	0.121
≥28	13 (23.6)	125 (34.2)	
Hypertension	19 (34.5)	143 (39.1)	0.520
Diabetes	11 (20.0)	34 (9.3)	0.017
Pulmonary disease	8 (14.5)	23 (6.3)	0.029
Past history of surgery on lower extremity	5 (9.1)	45 (12.3)	0.493
Cardiovascular disease	8 (14.5)	36 (9.8)	0.287
Hepatobiliary disease	4 (7.3)	29 (7.9)	0.867
ASA			0.949
1–2	49 (89.1)	325 (88.8)	
3–4	6 (10.9)	41 (11.2)	
Hypercholesterolemia	24 (43.6)	113 (30.9)	0.060
Hyperlipidemia	24 (43.6)	103 (28.1)	0.020
Smoking (yes)	6 (10.9)	43 (11.7)	0.856
Alcohol drinking (yes)	6 (10.9)	45 (12.3)	0.769
Sidedness			0.450
Left	32 (58.2)	193 (52.7)	
Right	23 (41.8)	173 (47.3)	
Radiographic K-L grade			0.468
II	21 (38.2)	109 (30.0)	
III	26 (47.3)	198 (54.5)	
IV	8 (14.5)	56 (15.4)	
Time to operation (days)	2.2 ± 2.0	1.9 ± 1.5	0.372
Intraoperative blood loss (ml)	130.4 ± 73.6	121.0 ± 54.7	0.261
Surgical duration	110.6 ± 40.4	104.5 ± 35.0	0.263
Incision length (≥ 8)	15 (27.3)	89 (24.3)	0.636
***Correction angle (°)**	9.4 ± 2.5	9.7 ± 2.7	0.577
Osteotomy gap filling (yes)	48 (87.3)	313 (85.5)	0.542
FBG (mmol/L)	5.7 ± 1.7	5.5 ± 1.3	0.295
AT III ≥100.0%	24 (43.6)	124 (33.9)	0.158
FDP ≥ 1.37 mg/L	24 (43.6)	130 (35.5)	0.244

Abbreviations: DVT, deep venous thrombosis; BMI, body mass index; K-L grade, Kellgren–Lawrence grade; ASA, American Society of Anesthesiologists; AT III, antithrombin III; FDP, fibrinogen degradation products; FBG, fasting blood glucose

*Correction angle was calculated by subtracting the preoperative Hip-Knee-Ankle Angle (HKA) from the preoperative HKA

Table 3 Multivariate analysis of factors associated with postoperative DVT following MOWHTO

Variables	OR	95% CI		*P*
		Lower limit	Upper limit	
Female (vs. male)	2.23	1.09	4.63	0.021
Diabetes	2.47	1.15	5.40	0.014
Hyperlipidemia	1.91	1.14	3.68	0.029

Abbreviations: OR, odds ratio; CI, confidence interval

enhanced monitoring and possibly additional prophylactic measures, such as a combination of pharmacologic and mechanical interventions (e.g., intermittent pneumatic compression devices or graduated compression stockings) [33, 34]. We propose that future clinical guidelines should include risk stratification tools to categorize patients into low, moderate, and high-risk groups, and for high-risk patients, more intensive prophylactic measures, including extended pharmacologic prophylaxis and early ambulation should be considered, ideally for a longer-duration.

This study had several strengths, including the inclusion of a large cohort of MOWHTO cases, the comprehensive evaluation of multiple laboratory indexes for their potential predictive or diagnostic ability in DVT, and the incorporation of various potential confounders for adjustment. However, several limitations should be noted. First, as a retrospective study, the inherent reliance on historical data introduces biases, including selection bias and information bias. This stems from the inclusion of only patients with complete medical records and follow-up data, which may not fully represent the general patient population. Additionally, it was likely that the patients' self-reported medical conditions were underestimated, potentially leading to an attenuation of the true association between these conditions and DVT risk. Second, while diabetes was identified as a risk factor for DVT, it remains unclear whether this effect is attributable to hyperglycemia itself or to the use of hypoglycemic medications, considering factors such as drug types, dose, and administration method. Furthermore, the severity of diabetes was not assessed using indicators like HbA1c, limiting our ability to determine its precisive relationship with DVT risk. Third, postoperative ultrasonography examination was performed between postoperative days 3 and 7 days, primarily based on the anticipated discharge timing; therefore, the 13.1% DVT rate should be cautiously interpreted withy caution, as it may not fully capture the temporal variability in thrombus formation. Fourth, several unmeasured confounders could not be accounted for, such as the duration of limb immobility before discharge and medication history (e.g., oral contraceptives or other pro-thrombotic drugs). These factors may contribute to residual confounding. Fifth, the single-center design may limit the external validity of our findings, potentially affecting their generalizability to other healthcare settings. Future multi-center studies are needed to validate our results in diverse patient populations. Further research should also explore novel predictive models, biomarker-based risk stratification, and the cost-effectiveness of different prophylactic strategies to optimize DVT prevention in high-risk patients.

In conclusion, we observed a 13.1% incidence of postoperative DVT following MOWHTO for medial compartment knee osteoarthritis with varus deformity, with 80% of cases classified as ICMVT. Laboratory indices demonstrated limited predictive value but may sever as supplementary tools in risk assessment. Three identified risk factors, albeit not modifiable, could help refine risk stratification, guiding targeted prophylaxis or treatment strageties.

Abbreviations

MOWHTO	Medial Opening Wedge High Tibial Osteotomy
DVT	Deep Venous Thrombosis
BMI	Body Mass Index
ASA	American Society of Anesthesiologists
SD	Standard Deviation
OR	Odds Ratio
CI	Confidential Interval
WBC	White Blood Cell
RBC	Red Blood Cell
KOA	Knee Osteoarthritis
FBG	Fasting Blood Glucose
ROC	Receiver Operating Characteristic
AUC	Area Under The Curve
FBG	Fasting Blood Glucose
INR	International Normalized Ratio
APTT	Activated Partial Thromboplastin Time
APTT-R	Activated Partial Thromboplastin Time Ratio
AT III	antithrombin III
FDP	Fibrinogen Degradation Products
TT	Thrombin Time
TT-R	Thrombin Time Ratio

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Author contributions
Y.Z. conceived and designed the study. S.Z., S.L. and C.J. collected the relevant data, performed the statistical analyses and prepared the figures and tables. W.T. and L.Q. interpreted the results. All the authors contributed to the preparation of the manuscript and consented the publication.

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Data availability
The data and materials used or analyzed during the study are not publicly available in accordance with our institutional policy, but are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Ethics Committee of the Hebei Medical University Third Hospital, which waived the requirement for informed consent. This study was carried in accordance with the Helsinki Declaration.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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