Original Research

Independent Risk Factors Associated With Venous Thromboembolism After Knee Arthroscopy

A Retrospective Study of 222 Patients

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Background: A serious complication after knee arthroscopy is venous thromboembolism (VTE), which includes both deep vein thrombosis (DVT) and pulmonary embolism (PE). However, asymptomatic VTE is frequently undetected.

Purpose: To (1) report the incidence of VTE after knee arthroscopy using ultrasound examination and computed tomography pulmonary angiography (CTPA) and (2) discover the independent risk factors of VTE after knee arthroscopy and determine the corresponding cutoff values of these indicators.

Study Design: Case-control study; Level of evidence, 3.

Methods: Included were 222 patients (115 male) who underwent arthroscopic knee procedures between October 2022 and January 2023. Baseline characteristics, blood test results, and VTE assessments were collected. During the 2-week follow-up, routine lower extremity vascular ultrasound was applied for DVT measurement, with CTPA evaluation for suspected PE. Patients were allocated into VTE and no-VTE groups, and descriptive statistics were used to analyze baseline data. Logistic regression analysis was used to determine the correlation between binary variables and the presence of postoperative VTE. Multivariate logistic regression analysis was further performed to determine the independent risk factors of VTE.

Results: Of the 222 patients, 37 (16.7%) had DVT and 1 (0.5%) had both DVT and PE. Compared to the no-VTE group, the VTE group was significantly older, with more female patients; higher body mass index (BMI) and postoperative D-dimer level; and higher rates of hypertension, hyperlipidemia, varicose veins of the lower extremity, and abnormal postoperative fibrin degradation product level ($P \leq .043$ for all). Notably, operative time >20 minutes was not significantly associated with postoperative VTE ($P = .513$). The independent risk factors for VTE included age >32 years (odds ratio [OR], 20.71 [95% CI, 4.40-97.47]; $P < .001$), BMI >23 kg/m^2 (OR, 3.52 [95% CI, 1.11-11.14]; $P = .032$), hyperlipidemia (OR, 6.81 [95% CI, 1.86-24.88]; $P = .004$), and postoperative D-dimer level >0.63 mg/L (OR, 34.01 [95% CI, 7.36-157.07]; $P < .001$).

Conclusion: The incidence of VTE after knee arthroscopy was 16.7% at the 2-week follow-up. Age >32 years, BMI >23 kg/m^2, hyperlipidemia, and postoperative D-dimer >0.63 mg/L were independent risk factors of postoperative VTE within 2 weeks after knee arthroscopy. For patients with knee arthroscopy, the cutoff value of postoperative D-dimer for VTE was found to be 0.63 mg/L for timely intervention.

Keywords: age; body mass index; hyperlipidemia, D-dimer; knee arthroscopy; venous thromboembolism

Knee arthroscopy is a widely performed orthopaedic procedure,[19,35] with an outstanding reputation as a minimally invasive operation with a rapid recovery, which may show less propensity for the incidence of postoperative complications compared to conventional open surgeries.[29]

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Nevertheless, the complications of arthroscopic surgeries are still widely reported in the literature, such as arthrofibrosis,[16] bleeding,[2] and septic arthritis.[49] In particular, venous thromboembolism (VTE), which includes deep vein thrombosis (DVT) and pulmonary embolism (PE), is one of the most common and serious consequences after arthroscopy that is strongly linked to considerable mortality and therefore merits more attention.[5,34,40]

In addition to being a sudden acute syndrome, VTE is a persistent chronic condition with a high recurrence rate, an annual incidence of 1 to 3 instances per 1000 people worldwide.[24] Notably, annual occurrences of VTE are estimated to cost the United States health care system $7 to $10 billion each year, with average medical costs of $18,000 to $23,000 for each survivor.[23] The rate of experiencing symptomatic VTE within 35 days after major orthopaedic surgery without therapy, according to the 2012 American College of Chest Physicians guidelines, was reported to be approximately 4.3%.[19] Other studies have reported that the incidence of VTE in patients undergoing knee arthroscopy without thromboprophylaxis ranged between 4.1% and 17.9%.[7,11,18,27,44,55,61]

In this context, low–molecular weight heparin is recommended as a first-line option among various interventions for thromboprophylaxis in major orthopaedic surgery because of its effectiveness and safety profile, and direct oral anticoagulants, such as apixaban, dabigatran, and rivaroxaban, are acceptable substitutes.[19,25] Notably, Nemeth et al[46] carried out a meta-analysis and found that patients receiving thromboprophylaxis, such as low–molecular weight heparin, during various arthroscopic knee surgeries had a noticeably lower incidence of VTE (both asymptomatic and symptomatic) at 1.6% (95% CI, 0.7-2.4), in contrast to those not receiving such treatment, who had a significantly higher incidence of VTE at 5.6% (95% CI, 2.7-8.5). This indicated that an early diagnosis and a subsequent timely treatment for VTE might be a critical bailout for severely symptomatic VTEs, even PE, in the perioperative period.

It has also been reported that asymptomatic VTE occurs approximately 10 times more frequently than symptomatic VTE after knee arthroscopy, indicating the VTE tends to be occult and the occurrence rate might be underestimated clinically.[46] The available long-term follow-up data on asymptomatic DVT after knee arthroscopy without anticoagulant treatment are scarce, leading to ongoing controversy regarding its clinical significance and management. It has been observed that patients with asymptomatic DVT have a higher incidence of distal DVT.[45] Although distal DVT has demonstrated a lower annualized incidence of overall VTE recurrence compared to proximal DVT, it carries a similar risk of serious recurrent VTE, which requires attention.[20] Singh et al[54] reported that patients who have undergone orthopaedic procedures may have an increased likelihood of clot propagation, and they recommended full anticoagulation until the follow-up duplex scan is negative. Furthermore, according to the CHEST Guideline,[33] patients with DVT provoked by surgery, whether it is a proximal DVT or an isolated distal DVT, are recommended to receive anticoagulation treatment for a duration of 3 months. In this regard, more focus should be placed on identifying the typical risk factors of VTE and the corresponding cutoff values to receive prompt treatment after arthroscopy, which would take into account the merits of early diagnosis and further optimize the decision-making system for thromboprophylaxis after arthroscopic knee surgeries.

At our institution, we routinely apply lower extremity vascular ultrasound in patients after knee arthroscopy for postoperative monitoring, with further evaluation using computed tomography pulmonary angiography (CTPA) for clinically suspected PE. In this study, we aimed to (1) report the general incidence of VTE using ultrasound examination and CTPA and (2) further identify the typical risk factors of VTE and the corresponding cutoff values after knee arthroscopy. We hypothesized that (1) the actual incidence of VTE via routine examination would be relatively higher than those reported based on symptomatic assessments in the literature; (2) patient age, body mass index (BMI), surgery type, duration of surgery, and postoperative D-dimer level would be characteristic risk factors associated with VTE after knee arthroscopy; and (3) the conventional cutoff values for some predictors would need to be adjusted correspondingly.

METHODS

Study Population

The protocol for this retrospective study was approved by the institutional review board of our institution, and the requirement for informed consent was waived. We reviewed a total of 425 patients aged <70 years who underwent arthroscopic knee procedures performed by 6 surgeons (J.Z., X.H., X.Y., G.X., S.Z., C.X.) in our institution

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Ethical approval for this study was obtained from Shanghai Sixth People's Hospital (ref No. 2022-KY-183(K)).

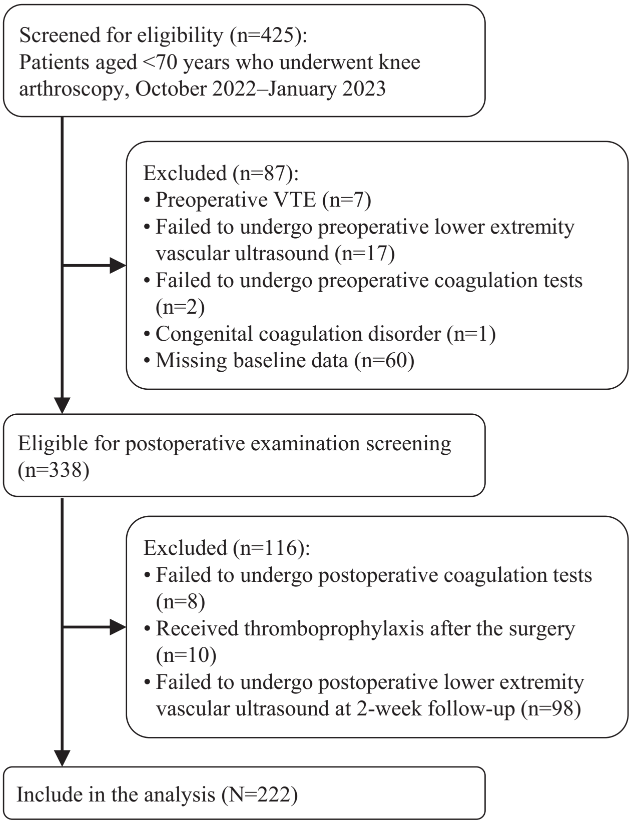

Figure 1. Flowchart of patient selection. VTE, venous thromboembolism.

between October 2022 and January 2023. Patients were excluded from this study if they met any of the following criteria: (1) preoperative VTE; (2) did not undergo preoperative lower extremity vascular ultrasound; (3) did not undergo preoperative coagulation tests; (4) congenital coagulation disorder; and (5) loss of baseline data. Moreover, among the 338 patients eligible for postoperative examination screening, 116 patients who did not perform postoperative coagulation tests, received thromboprophylaxis after the surgery, or did not undergo postoperative lower extremity vascular ultrasound during a 2-week follow-up period were also excluded. Ultimately, 222 patients were included in this study (Figure 1).

Arthroscopic Surgery

Arthroscopic ligament reconstructions with bone tunnels are presumed more complex and invasive than routine arthroscopic procedures, such as meniscectomy, leading to a reportedly increased risk for DVT.[22,30,55] In this context, patients with both basic and more complex arthroscopic surgeries were included in our study to verify the effects of procedure types on VTE. The basic surgeries included meniscal surgery (repair or meniscectomy),[10] cyst removal, loose body removal, internal fixation removal, synovectomy, joint debridement, and joint release.[39,55] The more complex surgeries included ligament reconstructions, such as anterior cruciate ligament reconstruction (ACLR),[42,52] posterior cruciate ligament reconstruction (PCLR),[4] medial patellofemoral ligament reconstruction (MPFLR),[50] and multiple ligament reconstruction. Among the 222 study patients, 118 (53.2%) patients underwent basic arthroscopic procedures, while 104 (46.8%) underwent complex arthroscopic procedures.

Data Collection

To ensure a comprehensive preoperative medical evaluation, all included patients completed a questionnaire addressing potential risk factors for VTE, and they underwent routine lower extremity vascular ultrasound and preoperative blood tests. In addition, all patients underwent coagulation testing on the first postoperative day and a lower extremity vascular ultrasound examination at the 2-week follow-up. Patients with a high clinical suspicion of PE underwent CTPA for further assessment. Among the various imaging tests for PE, CTPA is one of the best-validated tests and is favored because of its higher sensitivity and simpler reporting system.[34,59]

Preoperative Questionnaire. For baseline data collection, patients completed a preoperative questionnaire with their doctor's assistance. Patients were asked to provide their age, sex, BMI, and binary (*yes*/*no*) responses to the following items: hypertension; hyperlipidemia; diabetes; smoking; chest tightness; varicose veins of the lower extremity; abnormal pulmonary function; history of unexplained or habitual abortion (≥3; in women); oral contraceptives or hormone replacement therapy (in women); malignancy; immobilizing plaster cast; history of VTE; family history of VTE; and history of hip, pelvis, or leg fracture. We determined most items in this questionnaire (eg, varicose veins, abnormal pulmonary function, and history of unexplained or habitual abortion) based on the 2005 Caprini risk assessment model, the most widely used and well-validated VTE risk prediction model for patients after surgery.[3,8,47,48,64] Risk factors such as hypertension, hyperlipidemia, diabetes, and smoking were also included because they have been reported to be potentially related to VTE.[1,53,57] Hypertension was defined as having a systolic blood pressure of ≥140 mm Hg, a diastolic blood pressure of ≥90 mm Hg during rest, or the use of antihypertensive medication within 2 weeks.[58] Hyperlipidemia was diagnosed when total cholesterol level was ≥240 mg/dL, triglycerides level was ≥200 mg/dL, low-density lipoprotein cholesterol level was ≥160 mg/dL, or there was a history of hyperlipidemia.[37] Diabetes was defined as a fasting plasma glucose level of ≥7 mmol/L or a history of diabetes.[38] Smoking status was defined as current smoking or a history of smoking.

Postoperatively, the duration of surgery and surgery type (basic vs complex) were collected from the surgical records. With more than 20 years of arthroscopic surgery expertise and >600 procedures each year, 1 of the 6 doctors (J.Z.) was considered the senior surgeon, while the others were junior surgeons (X.H., X.Y., G.X., S.Z., C.X.).

Blood Tests. The lipid panel blood and blood glucose tests were completed before surgery for hyperlipidemia and diabetes assessments. Coagulation tests were assessed before and on the first day after surgery. The INNOVANCE D-dimer assay, an immunoturbidimetric assay, was utilized to detect D-dimer levels, with a preoperative D-dimer level of >0.5 mg/L considered abnormal.[34] The postoperative D-dimer value was recorded. Prothrombin time <11 seconds, fibrin degradation product (FDP) level >5.0 mg/L, fibrinogen >4 g/L, and antithrombin III activity <75% were considered abnormal.[9,28,51]

VTE Measurements. In this study, lower extremity ultrasound was used for DVT measurement, including using compression, color, and spectral Doppler sonography to assess phasicity and venous flow augmentation of both legs.[32] The primary diagnostic criteria for acute DVT was the incompressibility of the vein.[56] The secondary diagnostic criteria were echogenic thrombus within the vein lumen, venous distention, loss of color or spectral Doppler signal within the vein lumen, absence of flow phasicity, and loss of response to Valsalva or augmentation.[56] The clinical signs of symptomatic DVT include leg pain, swelling, redness, and a positive Homan test.[34] When combined with acute dyspnea, chest pain, tachypnea, or hypoxemia,[14] DVT patients required CTPA for suspected PE.

Based on the VTE measurements, all included patients were allocated into VTE and no-VTE groups.

Statistical Analysis

Various baseline characteristics and blood test data were divided into continuous and nominal variables. Descriptive statistics were used to analyze baseline data. The chisquare or Fisher exact test was used to compare nominal variables between the VTE and no-VTE groups. The continuous variables were compared between the 2 groups using the Wilcoxon signed-rank test. The descriptive statistics for continuous variables were represented as means ± standard deviations, while those for nominal variables were expressed based on numbers and percentage, denoted as n (%).

Then the receiver operating characteristic (ROC) curve was used to calculate the area under the ROC curve (AUC) and obtain the cutoff values of the continuous variables between the DVT and no-DVT groups using the maximum Youden indexes (calculated as sensitivity + specificity – 1).[63] These continuous variables were dichotomized to the corresponding binary variables based on their cutoff values.

Binary logistic regression analysis was used to evaluate the association between each binary variable and the presence of postoperative VTE. Thereafter, all variables with $P < .05$ in the binary logistic regression were included in a multivariate logistic regression analysis to predict VTE. A post hoc power analysis was performed with an α error of .05. For the multivariate logistic regression analysis, odds ratios (ORs) and 95% CIs were reported. Statistical significance was set at $P < .05$. All statistical analyses were performed using SPSS Version 25 (IBM).

Based on previous studies,[7,27,55,61] the incidence of VTE was hypothesized as 10%. Both the sensitivity and specificity of the new D-dimer cutoff point were set at 70%, and the covariates were expected to have a moderate association with postoperative D-dimer status as R was set at 0.50. A minimum sample size of 190 patients was required with an α error of .05 and a power of 0.8 (G*Power 3.1.9.7; Heinrich Heine University Düsseldorf).

RESULTS

Patient Characteristics

Among our cohort of 222 patients, 37 (16.7%) were diagnosed with DVT using lower extremity vascular ultrasound, with 10 patients having symptomatic DVT and 2 having proximal DVT, and 1 patient having both DVT and PE. The mean age, BMI, duration of surgery, and postoperative D-dimer level of the overall cohort were 33.6 ± 14.0 years, 23.8 ± 3.5 kg/m^2, 46.2 ± 24.7 minutes, and 0.85 ± 1.12 mg/L, respectively.

The age, rate of hyperlipidemia, postoperative D-dimer level, and rate of abnormal postoperative FDP level were significantly higher in the VTE group compared to the no-VTE group ($P < .001$ for all) (Table 1). The proportion of female patients ($P = .026$), BMI ($P = .019$), and rate of hypertensive patients ($P = .043$) as well as those with varicose veins of the lower extremity ($P = .021$) were also significantly higher in the VTE group compared to those in the no-VTE group.

ROC Analysis

The ROC analyses were performed based on the continuous variables between the DVT and no-DVT groups: age; BMI; duration of surgery; and postoperative D-dimer level (Table 2 and Figure 2). The ROC curves indicated that the cutoff value for age was 32 years, with a sensitivity and specificity of 89.2% and 61.6%, respectively (AUC = 0.875). The cutoff value for BMI was 23 kg/m^2, with a sensitivity and specificity of 75.7% and 48.6%, respectively (AUC = 0.622). The cutoff value for duration of surgery was 20 minutes, with sensitivity and specificity of 94.6% and 8.6%, respectively (AUC = 0.460), and the cutoff value for postoperative D-dimer level was 0.63 mg/L, with sensitivity and specificity of 86.5% and 73.0%, respectively (AUC = 0.811). These continuous variables were therefore dichotomized into corresponding binary variables based on the aforementioned cutoff values for further logistic regression analysis.

Multivariate Logistic Regression Analysis

The results of the logistic regression analysis for the association between each binary variable and the presence of postoperative VTE are shown in Table 3. Female sex, age >32 years, BMI >23 kg/m^2, hypertension, hyperlipidemia, diabetes, varicose veins of the lower extremity, postoperative D-dimer level >0.63 mg/L, and abnormal postoperative

TABLE 1
Baseline Patient Characteristics[a]

Characteristic	Total (n = 222)	DVT (n = 37)	No DVT (n = 185)	*P*
Sex, male/female, n	115/107	13/24	102/83	**.026**
Age, y	33.6 ± 14.0	46.1 ± 11.1	31.1 ± 13.1	<**.001**
BMI, kg/m^2	23.8 ± 3.5	25.0 ± 3.2	23.6 ± 3.5	**.019**
Duration of surgery, min	46.2 ± 24.7	43.2 ± 22.8	46.8 ± 25.1	.438
Surgery type, basic/complex, n[b]	118/104	20/17	98/87	.904
Surgeon, junior/senior, n[b]	88/134	17/20	71/114	.390
Hypertension[b]	17 (7.7)	6 (16.2)	11 (5.9)	**.043**
Hyperlipidemia[b]	36 (16.2)	14 (37.8)	22 (11.9)	<**.001**
Diabetes[b]	6 (2.7)	3 (8.1)	3 (1.6)	.060
Smoking[b]	29 (13.1)	3 (8.1)	26 (14.1)	.429
Chest tightness	6 (2.7)	2 (5.4)	4 (2.2)	.262
Varicose veins of the lower extremity	11 (5.0)	5 (13.5)	6 (3.2)	**.021**
Abnormal pulmonary function	2 (0.9)	0 (0)	2 (1.1)	>.999
History of unexplained or habitual abortion (≥3; in women)	3 (2.8)	0 (0)	3 (3.6)	>.999
Oral contraceptives or hormone replacement therapy (in women)	2 (1.9)	0 (0)	2 (2.4)	>.999
Malignancy	3 (1.4)	2 (5.4)	1 (0.5)	.073
Immobilizing plaster cast	4 (1.8)	0 (0)	4 (2.2)	>.999
History of VTE	2 (0.9)	0 (0)	2 (1.1)	>.999
Family history of VTE	1 (0.5)	0 (0)	1 (0.5)	>.999
History of hip, pelvis, or leg fracture	4 (1.8)	0 (0)	4 (2.2)	>.999
Abnormal preoperative D-dimer level	13 (5.9)	2 (5.4)	11 (5.9)	>.999
Abnormal preoperative PT[b]	19 (8.6)	5 (13.5)	14 (7.6)	.391
Abnormal preoperative FDP level[b]	2 (0.9)	0 (0)	2 (1.1)	>.999
Abnormal preoperative FIB[b]	1 (0.5)	0 (0)	1 (0.5)	>.999
Abnormal preoperative AT III activity[b]	2 (0.9)	0 (0)	2 (1.1)	>.999
Postoperative D-dimer level, mg/L	0.85 ± 1.12	1.83 ± 1.57	0.65 ± 0.89	<**.001**
Abnormal postoperative PT[b]	7 (3.2)	3 (8.1)	4 (2.2)	.093
Abnormal postoperative FDP level[b]	30 (13.5)	16 (43.2)	14 (7.6)	<**.001**
Abnormal postoperative FIB[b]	3 (1.4)	0 (0)	3 (1.6)	>.999
Abnormal postoperative AT III activity[b]	2 (0.9)	0 (0)	2 (1.1)	>.999

[a]Values are presented as n (%) or mean ± SD unless otherwise indicated. Boldface *P* values indicate a statistically significant difference between the study groups ($P < .05$). AT III, antithrombin III; FDP, fibrinogen degradation product; FIB, fibrinogen; PT, prothrombin time; VTE, venous thromboembolism.
[b]See the Methods section for definitions.

FDP level were found to be significantly associated with postoperative VTE ($P \le .045$ for all). Notably, operative time >20 minutes was not significantly associated with postoperative VTE (P = .513).

Multivariate Logistic Regression Model for Independent Risk Factors

The independent risk factors identified in the multivariate model for VTE included age >32 years (OR, 20.71 [95% CI, 4.40-97.47]; $P < .001$), BMI >23 kg/m^2 (OR, 3.52 [95% CI, 1.11-11.14]; P = .032), hyperlipidemia (OR, 6.81 [95% CI, 1.86-24.88]; P = .004), and postoperative D-dimer level >0.63 mg/L (OR, 34.01 [95% CI, 7.36-157.07]; $P < .001$) (Table 4).

TABLE 2
Cutoff Value and AUC from ROC Analysis[a]

Factor	Cutoff Value	AUC
Age, y	32	0.875
BMI, kg/m^2	23	0.622
Duration of surgery, min	20	0.460
Postoperative D-dimer level, mg/L	0.63	0.811

[a]The cutoff value was analyzed using the maximum Youden index (calculated as sensitivity + specificity − 1). AUC, area under the receiver operating characteristic curve; BMI, body mass index; ROC, receiver operating characteristic.

DISCUSSION

In this study, we identified the cutoff values of some indicators for VTE diagnosis and further determined the typically independent risk factors of VTE after arthroscopic knee surgeries for VTE prediction. The most important findings of the study were that (1) the incidence of VTE after knee arthroscopy was 16.7% at the 2-week follow-up via ultrasonography and CTPA when necessary; (2) the cutoff values of age, BMI, and postoperative D-dimer level for postoperative VTE diagnosis was 32 years,

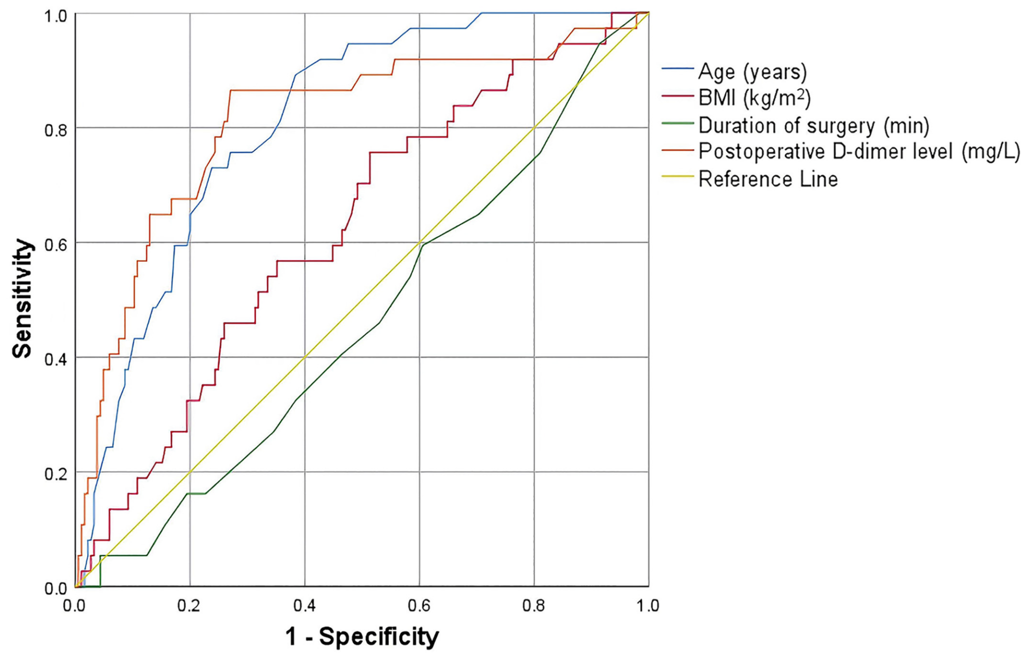

Figure 2. The receiver operating characteristic (ROC) analysis including age, BMI, duration of surgery, and postoperative D-dimer level. ROC curves were used to calculate the area under the ROC curve and obtain the cutoff values using the maximum Youden index (calculated as sensitivity + specificity – 1). BMI, body mass index.

23 kg/m^2, and 0.63 mg/L, respectively; and (3) age >32 years, BMI >23 kg/m^2, hyperlipidemia, and postoperative D-dimer level >0.63 mg/L were found to be independent risk factors of postoperative VTE, which merit more attention after arthroscopic knee surgery.

Notably, we observed an overall incidence of 16.7% for postoperative VTE during a 2-week postoperative period, using ultrasonography and CTPA when necessary. Previous studies have reported that VTE incidence without thromboprophylaxis had a wide range, from 4.1% to 17.9%.[7,11,18,27,44,55,61] Some studies applied venography for DVT assessment, the gold standard but an invasive method of diagnosis, and demonstrated relatively greater DVT incidences that were similar to ours.[11,55] However, multiple large retrospective studies using medical records from the database to identify VTE[21,39] showed that the incidences of postoperative VTE were very low, nearly 0.5%. The advantage of our study is that we found the incidence of DVT using ultrasonography to be close to that utilizing the invasive instrument since the possibility that the information bias of medical records and low-sensitivity detection technologies may lead to an underestimating of the actual incidence in some large retrospective studies. Our study indicated that routine lower extremity vascular ultrasonography after surgery might detect more potential DVTs that were previously missed in other studies and allow for early diagnosis and timely therapy.

Age is a well-known risk factor for VTE, which may be explained by increased systemic blood coagulation activation and decreased mobility.[55] Mauck et al[41] discovered that older age was associated with a higher probability of symptomatic VTE (hazard ratio = 1.34 for each 10-year increase in patient age; $P = .03$) after elective arthroscopic procedures. As for the threshold of age, Maletis et al[39] stated that the incidence of VTE after elective arthroscopic knee procedures was significantly greater in patients aged >50 years compared with younger patients, although the difference did not reach significance if DVT and PE odds were examined separately. In addition, Ye et al[62] studied 171 patients with venography after ACLR and reported that the risk of DVT (both asymptomatic and symptomatic) was significantly greater in patients aged ≥35 years ($P < .01$). Gaskill et al[21] performed a retrospective review of 15,767 patients with ACLRs and also showed that the odds of symptomatic VTE increased in patients aged ≥35 years (OR, 1.96 [95% CI, 1.27-3.04]; $P = .003$). Our research also revealed a correlation between age and DVT after knee arthroscopy. Meanwhile, we found the cutoff age of 32 years to be close to that in previous studies. Notably, the 2005 Caprini risk assessment model[3] for VTE assessments after open invasive surgeries set potential cutoff points at ages 40, 60, and 75 years. Further research is required to verify typically different cutoff points of other grades of age after arthroscopy.

Numerous studies examining the link between BMI and VTE concluded that the two are positively associated. Holler et al[26] analyzed 718,289 patients who underwent knee arthroscopy in the United States and reported that obesity was associated with increased odds of VTE. Traven et al[57] also demonstrated that obesity was a risk factor for VTE in patients undergoing knee arthroscopic surgery. In addition, a previous review highlighted the mechanistic role

TABLE 3
Results of Binary Logistic Regression Analysis for Presence of Postoperative VTE[a]

Risk Factor	*P*
Female sex	**.029**
Age >32 y	<**.001**
BMI >23 kg/m^2	**.008**
Surgery type	.904
Surgeon	.391
Hypertension	**.040**
Hyperlipidemia	<**.001**
Diabetes	**.045**
Smoking	.334
Chest tightness	.283
Varicose veins of the lower extremity	**.015**
Abnormal pulmonary function	.999
History of unexplained or habitual abortion (≥3; in women)	.999
Oral contraceptives or hormone replacement therapy (in women)	.999
Malignancy	.057
Immobilizing plaster cast	.999
History of VTE	.999
Family history of VTE	>.999
History of hip, pelvis, or leg fracture	.999
Abnormal preoperative D-dimer level	.898
Abnormal preoperative PT	.245
Abnormal preoperative FDP level	.999
Abnormal preoperative FIB	>.999
Abnormal preoperative AT III activity	.999
Duration of surgery >20 min	.513
Postoperative D-dimer level >0.63 mg/L	<**.001**
Abnormal postoperative PT	.078
Abnormal postoperative FDP level	<**.001**
Abnormal postoperative FIB	.999
Abnormal postoperative AT III activity	.999

[a]Boldface *P* values indicate statistical significance ($P < .05$). AT III, antithrombin III; BMI, body mass index; FDP, fibrinogen degradation product; FIB, fibrinogen; PT, prothrombin time; VTE, venous thromboembolism.

TABLE 4
Results of Multivariate Logistic Regression Analysis[a]

Risk Factor	OR (95% CI)	*P*
Female sex	0.95 (0.30-2.99)	.926
Age >32 y	20.71 (4.40-97.47)	<**.001**
BMI >23 kg/m^2	3.52 (1.11-11.14)	**.032**
Hypertension	0.39 (0.08-2.05)	.267
Hyperlipidemia	6.81 (1.86-24.88)	**.004**
Diabetes	4.21 (0.29-60.28)	.289
Varicose veins of the lower extremity	1.47 (0.29-7.33)	.641
Postoperative D-dimer level >0.63 mg/L	34.01 (7.36-157.07)	<**.001**
Abnormal postoperative FDP	1.80 (0.54-5.94)	.337

[a]Boldface *P* values indicate statistical significance ($P < .05$). BMI, body mass index; FDP, fibrinogen degradation product.

of chronic inflammation and poor fibrinolysis in mediating obesity-related thrombosis.[6] Nevertheless, the association between BMI and VTE after knee arthroscopy was still not specific in the 2019 International Society on Thrombosis and Haemostasis Annual Congress guideline, even if BMI >25 kg/m^2 was agreed as a risk factor (OR = 1.8) in major orthopaedic surgery.[31] The threshold of BMI in previous studies and the 2005 Caprini risk assessment model[3] were set at 25, which differ from our cutoff point of 23 kg/m^2. We should note that the World Health Organization (WHO) expert meeting in 2004 acknowledged that the cutoff point for observed risk was in the range of 22 to 25 kg/m^2 in different Asian groups, which is lower than the current WHO cutoff point for overweight (>25 kg/m^2).[60] Therefore, the discrepancy between the conventional BMI cutoff point for VTE assessment and ours could be attributed to the potential ethnic and regional diversity inherent in BMI. Moreover, the WHO consultation[60] similarly identified a potential public health action point of 23 kg/m^2 as a risk factor for increased risk in many Asian communities, which interestingly is congruent with the cutoff value determined in our study. However, BMI >23 kg/m^2 was characteristically demonstrated as a risk factor for VTE after knee arthroscopy in our study group from an Asian community, which is lower than the global standard cutoff value of overweight. This may encourage more investigations to determine the discrepancy of BMI cutoff in different study populations for predicting VTE after knee arthroscopy.

It is noteworthy that the association between hyperlipidemia and VTE incidence is not yet clear. According to previous studies, hyperlipidemia was linked to increased coagulability, endothelial dysfunction, and platelet aggregation, all of which may raise the risk of VTE.[13,17] Moreover, in a meta-analysis of 21 case-control and cohort studies including 63,552 individuals, Ageno et al[1] found a positive relationship between hyperlipidemia and the incidence of VTE. However, the association between hyperlipidemia and VTE after knee arthroscopy has not been documented by high-quality studies. In this study, we found that hyperlipidemia was significantly associated with postoperative VTE in both binary logistic regression and multivariate analysis. Although further studies are required for a basic, comprehensive understanding of the inner biochemical relationships between hyperlipidemia and VTE, we should pay close attention to patients with hyperlipidemia after arthroscopic knee surgeries based on the current clinical evidence in our findings. Perioperative hypolipidemic therapy may effectively reduce the risk of VTE, which needs high-level cohort studies or randomized controlled trials and basic evidence to further determine in the future.

The D-dimer test has always needed to be sensitive because it is essential for the early diagnosis of VTE, which inevitably sacrifices some specificity.[59] In patients with normal levels, a negative D-dimer test can therefore effectively rule out the probability of VTE.[34] The standard threshold of D-dimer was conventionally recommended as 0.5 mg/L, although the diagnostic accuracy has been influenced by different D-dimer assays.[12,34] Due to the lower accuracy of the D-dimer test in older patients, Douma et al[15] established an age-adjusted cutoff point, defined as “patient age × 10 μg/L” in patients aged >50 years, which may inspire us to detect characteristic cutoff values of D-dimer in different studied populations for VTE assessments.

To our knowledge, there is still uncertainty over how to treat patients with increased D-dimer levels after arthroscopic knee surgery since the cutoff value might differ from the conventional value depending on patient characteristics and the invasiveness of the surgical procedure. D-dimer levels are elevated in most patients after arthroscopic knee surgery based on the current standard (0.5 mg/L), which may confuse doctors because simple intervention may result in overtreatment and increased undesirable bleeding events according to the conventional cutoff value. In contrast, undertreatment may result in undesirable thrombosis events. These 2 severe postoperative complications may place doctors in a dilemma when making clinical decisions. Our findings provide evidence to assess the risk of VTE based on D-dimer levels with a new warning point since previous research has not clearly defined a threshold for timely intervention, particularly in knee arthroscopy. Based on the findings of our study, we advise monitoring individuals with postoperative D-dimer levels >0.63 mg/L. Compared to the conventional cutoff value of 0.5 mg/L, this level provides less propensity for undesirable postoperative bleeding resulting from excessive anticoagulation by overtreatment, which may establish a new standard to assess the risk of postoperative thrombosis for arthroscopic knee surgery and optimize the decision-making strategies for early diagnosis and subsequent timely treatment for VTE.

Despite significant research efforts to identify risk factors for VTE, many patients with asymptomatic VTE may go undiagnosed due to a lack of routine postoperative examination. This can lead to an underestimation of the risk of VTE after arthroscopic surgery and impede the identification of risk factors. In the current study, we applied routine lower extremity vascular ultrasound postoperatively for VTE assessments, a first-line imaging modality,[34,36,43] and further screened out a variety of variates through binary logistic regression; we then conducted a comprehensive multivariable logistic regression analysis to determine the independent risk factors for VTE after arthroscopic knee surgery. In addition, the ROC analysis identified precise cutoff values for these essential indicators of VTE after arthroscopic knee surgery, highlighting some variations from those typically used for other procedures, such as the D-dimer. This finding may be useful in identifying the risk factor cutoff values that are characterized for arthroscopic knee surgery and in assisting sports medicine specialists in recognizing and treating VTE early in the postoperative period. For patients with ≥1 multiple risk factors, we recommended undergoing routine postoperative ultrasound examinations for early detection. Furthermore, future studies with larger cohorts are needed to further investigate the specific higher-risk populations that would benefit from ultrasound screening.

Limitations

This study has some limitations. First, the sample size of our study population was relatively small because we used lower extremity ultrasound to assess DVT and CTPA for suspected PE when necessary, which made patient inclusion and follow-up more challenging. Even though we estimated our sample size had achieved a power >80%, we should confirm several risk factors that were not significantly associated with VTE in our upcoming investigations with larger cohorts. Second, this work did not consider the long-term follow-up results but only reflected the risk of short-term (2-week follow-up) VTE. However, limited studies regarding arthroscopy[41,44] have reported that over 75% of VTE events occurred within the first 14 postoperative days. Longer-term follow-up data should be gathered in future research for more convincing analyses of the full rehabilitation process after knee arthroscopy. Third, the cutoff values provided in our study were derived from data collected within 2 weeks postoperatively and may be limited for long-term prediction, whereas they may be more appropriate for short-term diagnosis after surgery. Since the postoperative coagulation status changes with time and the VTE events may occur at longer-term follow-up, the update of cutoff values at various follow-up stages requires further research. Lastly, we did not further analyze VTE risk factors according to surgery type (basic vs complex). Although our study showed that surgery type was not associated with postoperative VTE after knee arthroscopy, the independent risk factors and the cutoff point may change in different groups based on the surgery type.

CONCLUSION

The findings of the current study demonstrated that the incidence of VTE after knee arthroscopy was 16.7% via ultrasonography and CTPA at the 2-week follow-up. In addition, age >32 years, BMI >23 kg/m^2, hyperlipidemia, and postoperative D-dimer >0.63 mg/L were independent risk factors of postoperative VTE within 2 weeks after knee arthroscopy. The cutoff value of postoperative D-dimer for VTE was established as 0.63 mg/L for patients undergoing knee arthroscopy.

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