

Predictive value of perioperative hypothermia for postoperative muscular calf vein thrombosis after total knee arthroplasty: a retrospective cohort study

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Abstract

Objective

To investigate the association between perioperative hypothermia and postoperative muscular calf vein thrombosis (MCVT) in patients undergoing total knee arthroplasty (TKA), and to evaluate the predictive performance of perioperative core temperature indicators for postoperative MCVT.

Methods

This retrospective cohort study included 903 patients who underwent TKA at a tertiary orthopaedic hospital in Henan Province, China, between January 1, 2023, and September 1, 2025. Postoperative MCVT was diagnosed using bilateral lower-limb Doppler ultrasound. Perioperative core temperature was recorded at predefined time points before, during, and after anaesthesia. Univariable analyses and multivariable logistic regression were performed to identify factors associated with postoperative MCVT. Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive performance of perioperative core temperature indicators.

Results

The study included 903 patients who underwent TKA, of whom 162 developed postoperative MCVT, corresponding to an incidence of 17.9%. Multivariable logistic regression demonstrated that core temperature at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia were independently associated with postoperative MCVT. Coagulation-related indicators, including PT, APTT, TT, FIB, and D-dimer, were also significantly associated with postoperative MCVT. ROC analysis showed that core temperature 1h after anaesthesia induction had the highest predictive performance among the temperature indicators, with an AUC of 0.755, sensitivity of 83.33%, and specificity of 67.61%. Core temperature at anaesthesia induction showed high sensitivity, with an AUC of 0.734, sensitivity of 93.21%, and specificity of 53.58%, while core temperature at emergence from anaesthesia showed an AUC of 0.704, sensitivity of 82.72%, and specificity of 58.16%.

Conclusion

The current analysis suggested that perioperative hypothermia was significantly associated with postoperative MCVT in patients who underwent TKA. Core temperature at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia showed predictive value for postoperative MCVT, with the 1h post-induction temperature demonstrating the best performance. These findings provide evidence for targeted temperature monitoring and early thrombotic risk identification after TKA.

Further prospective studies are needed to confirm whether maintaining perioperative normothermia can reduce postoperative MCVT.

Introduction

Deep vein thrombosis (DVT) is a major postoperative complication after TKA and remains an important cause of morbidity, disability, and potentially fatal pulmonary embolism [1, 2]. MCVT, a common form of distal venous thrombosis involving the gastrocnemius or soleal veins, has been increasingly recognized as a clinically relevant precursor of proximal DVT [3, 4]. Although MCVT is often considered less severe than proximal DVT, previous studies have reported that approximately 23%–41% of patients with MCVT may experience thrombus progression or develop DVT, and pulmonary embolism has been identified in a proportion of affected patients[5–7]. However, MCVT frequently presents with subtle or nonspecific symptoms, which increases the risk of delayed diagnosis, underdiagnosis, and missed diagnosis in routine clinical practice [8, 9]. Moreover, the clinical characteristics, progression patterns, and optimal management strategies for MCVT remain insufficiently defined. Therefore, improving the early identification and prediction of MCVT after TKA is essential for optimizing perioperative thromboprophylaxis and reducing thromboembolic complications (Fig. 1).

Inadvertent perioperative hypothermia (IPH), commonly defined as a core body temperature below 36.0°C, is a frequent and preventable adverse event during the perioperative period[10]. Patients undergoing major orthopaedic surgery are particularly susceptible to IPH because of anaesthesia-induced thermoregulatory impairment, surgical exposure, infusion of unwarmed fluids, and prolonged operative duration[11]. Previous studies have reported that the incidence of IPH in major orthopaedic surgery varies widely, ranging from 25.7% to 90%, while the incidence among patients undergoing TKA has been reported to be approximately 28%–36% [12, 13]. IPH may adversely affect postoperative recovery by increasing the risk of blood loss, transfusion, cardiovascular events, postoperative shivering, delayed emergence from anaesthesia, immune dysfunction, and surgical site infection[14]. More importantly, hypothermia may impair coagulation and fibrinolytic function, alter platelet activity, and disturb peripheral microcirculation, thereby potentially contributing to a prothrombotic state in patients after TKA.

Despite increasing attention to perioperative temperature management, the association between IPH and postoperative MCVT after TKA remains unclear. Existing studies have mainly focused on the effects of IPH on bleeding, infection, cardiovascular events, and anaesthetic recovery, whereas limited evidence is available regarding its potential role in thrombus formation, particularly MCVT. Given that perioperative body temperature is routinely monitored and potentially modifiable, clarifying its relationship with MCVT may provide a practical basis for early thrombotic risk stratification and targeted prevention in patients undergoing TKA.

Therefore, this retrospective cohort study analysed electronic medical records of patients who underwent TKA at a tertiary orthopaedic hospital. The objectives were to investigate the association

between perioperative hypothermia and postoperative MCVT, to examine its relationship with blood pressure and coagulation-related indicators, and to evaluate the predictive value of body temperature at different perioperative time points for MCVT. The findings may help identify a clinically accessible and modifiable risk indicator for MCVT and provide evidence for improving perioperative thrombosis prevention strategies after TKA.

Methods

Study design and setting

This retrospective cohort study was conducted at Luoyang Orthopedic Hospital of Henan Province, a tertiary orthopedic hospital in China. Clinical data were obtained from the electronic medical records of patients who underwent total knee arthroplasty between January 1, 2023, and September 1, 2025. A total of 903 eligible patients were included in the final analysis.

Participants and eligibility criteria

Patients who underwent total knee arthroplasty during the study period were screened for eligibility. The inclusion criteria were as follows: 1) age ≥ 18 years; 2) underwent primary total knee arthroplasty; and 3) had available postoperative bilateral lower-limb venous Doppler ultrasound results for the assessment of muscular calf vein thrombosis. MCVT was diagnosed based on postoperative lower-limb venous Doppler ultrasound findings. Patients were classified into the MCVT group or the non-MCVT group according to the postoperative ultrasound results.

The exclusion criteria were as follows: 1) pre-existing MCVT or other venous thrombosis at admission; 2) hospitalization duration < 48 hours; 3) venous thrombosis at sites other than the muscular calf veins; 4) pre-existing hematological diseases or known coagulation disorders; 5) history of malignant neoplasms; and 6) incomplete medical records or records with obvious errors that could not be verified.

Data collection

Medical records at Luoyang Orthopedic Hospital of Henan Province are managed using the International Classification of Diseases, 10th Revision (ICD-10) coding system. Eligible patients who underwent total knee arthroplasty between January 1, 2023, and September 1, 2025, were identified through the iMedical HIS 9.1.1 electronic medical record system using inpatient identification numbers and procedure-related information. Relevant clinical data were then extracted from the electronic medical record system according to the predefined study variables.

To ensure data accuracy and consistency, all data collectors received standardized training before data extraction, including training on variable definitions, extraction procedures, and quality-control requirements. Three trained researchers participated in data collection. Two researchers independently

extracted and double-entered the data using SPSS version 26.0, and a third researcher performed cross-checking. Any discrepancies, missing items, or implausible values were reviewed against the original electronic medical records and corrected where appropriate.

The extracted variables included demographic characteristics, clinical indicators, coagulation-related parameters, and perioperative body temperature measurements. Demographic variables included sex, age, marital status, educational level, occupation, type of medical insurance/payment, and body mass index (BMI), calculated as weight in kilograms divided by height in metres squared. Clinical variables included standardized anticoagulant use, postoperative heart rate, postoperative systolic blood pressure, postoperative diastolic blood pressure, fasting plasma glucose, and coagulation-related indicators, including prothrombin time, activated partial thromboplastin time, thrombin time, fibrinogen, and D-dimer. Perioperative body temperature was collected at the following time points: before anaesthesia, at induction of anaesthesia, 1 hour after anaesthesia, 2 hours after anaesthesia, at the end of surgery, upon emergence from anaesthesia, at anaesthesia recovery, and 30 minutes after returning to the ward.

Statistical analysis

A parallel double-entry method was used to establish the study database. Data processing and statistical analyses were performed using SPSS version 26.0 and MedCalc version 20.2. Categorical variables are presented as frequencies and percentages, and comparisons between the MCVT and non-MCVT groups were performed using the chi-square test or Fisher's exact test, as appropriate.

The Kolmogorov–Smirnov test was used to assess the normality of continuous variables. As none of the continuous variables followed a normal distribution, continuous variables are presented as medians and interquartile ranges [M (*P*25, *P*75)], and between-group comparisons were performed using the Mann–Whitney U test.

Univariable and multivariable logistic regression analyses were performed to identify factors associated with postoperative MCVT. Variables with statistical significance in the univariable analysis and clinically relevant variables were considered for inclusion in the multivariable logistic regression model. The goodness of fit of the logistic regression model was evaluated using the Hosmer–Lemeshow test. Receiver operating characteristic curve analysis was performed using MedCalc version 20.2 to evaluate the predictive performance of perioperative body temperature and other relevant factors for MCVT. The area under the curve, sensitivity, specificity, and corresponding 95% confidence intervals were calculated.

All statistical tests were two-sided, and a $P < 0.05$ was considered statistically significant.

Results

General characteristics of the study population

A total of 927 medical records of patients who underwent total knee arthroplasty were initially reviewed. After excluding records with incomplete or invalid data, 903 patients were included in the final analysis, corresponding to a valid data rate of 97.4%. Among the included patients, 430 were male and 473 were female. The median age was 61 years in the non-MCVT group and 63 years in the MCVT group.

According to the results of postoperative bilateral lower-limb venous Doppler ultrasound, 162 patients developed muscular calf vein thrombosis, giving an incidence of 17.9%, whereas 741 patients did not develop MCVT, accounting for 82.1% of the study population.

Comparisons of baseline and clinical characteristics between the MCVT and non-MCVT groups are shown in Table 1. Significant differences were observed between the two groups in sex, occupation, standardised anticoagulant use, postoperative systolic blood pressure, prothrombin time, activated partial thromboplastin time, thrombin time, fibrinogen, and D-dimer levels. Compared with patients without MCVT, patients with MCVT had higher postoperative systolic blood pressure, higher fibrinogen and D-dimer levels, and different distributions of sex, occupation, and anticoagulant use. In addition, prothrombin time, activated partial thromboplastin time, and thrombin time differed significantly between the two groups.

No statistically significant differences were observed between the two groups in age, marital status, educational level, source of medical payment, body mass index, postoperative heart rate, postoperative diastolic blood pressure, or fasting plasma glucose.

Table 1

Patient characteristics and associated postoperative mcvt incidence in total knee arthroplasty

Variable	N (%)	N (%)	Non-MCVT group (n = 741)	MCVT group (n = 162)	χ^2/Z	P
Sex	Male	430(47.6)	367(49.5)	63(38.9)	6.032	0.014
	Female	473(52.4)	374(50.5)	99(61.1)		
Age(years)		903	61(15)	63(13)	72.146	0.085
Marital Status	Single	25(2.8)	25(3.4)	0	6.341	0.096
	Married	849(94)	691(93.3)	158(97.5)		
	Divorce	2(0.2)	2(0.3)	0		
	Widowed	27(3)	23(3.1)	4(2.5)		
Educational Level	Primary school or below	393(43.5)	314(42.4)	79(48.88)	2.656 ^b	0.103
	Secondary education	435(48.2)	362(48.9)	73(45.1)		
	Tertiary education or higher	75(8.3)	65(8.8)	10(6.2)		
Occupation	Retired/Unemployed	129(14.3)	94(12.7)	35(21.6)	19.536	0.002
	student	20(2.2)	20(2.7)	0		
	Farmer	599(66.3)	491(66.3)	108(66.7)		
	Worker	45(5.0)	42(5.7)	3(1.9)		
	Self-employed	77(8.5)	69(9.3)	8(4.9)		
	Technical professional	33(3.7)	25(3.4)	8(4.9)		
Source of Medical Payment	Self-pay	45(5.0)	34(4.6)	11(6.8)	6.206	0.102
	New Rural Cooperative Medical Scheme (NRCMS)	550(60.9)	462(62.3)	88(54.3)		
	Urban Basic Medical Insurance	228(25.2)	177(23.9)	51(31.5)		
	Others	80(8.9)	68(9.2)	12(7.4)		

Note: a denotes chi-square test; b indicates the Mann–Whitney U test.; Abbreviations: HR, heart rate (bpm); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); FPG, fasting plasma glucose; PT, prothrombin time; APTT, activated partial thromboplastin time; TT, thrombin time; FIB, fibrinogen.

Variable	N (%)	N (%)	Non-MCVT group (n = 741)	MCVT group (n = 162)	χ^2/Z	P
BMI(kg/m ²)	< 18.5	24(2.7)	16(2.2)	8(4.9)	1.125 ^b	0.289
	18.5 ~ 24.0	237(26.2)	205(27.7)	32(19.8)		
	≥ 24.0	642(71.1)	520(70.2)	122(75.3)		
Anticoagulant Use	No	358(39.6)	308(41.6)	50(30.9)	6.362	0.013
	Yes	545(60.4)	433(58.4)	112(69.1)		
HR (bpm)			77(10)	76(10)	-0.215 ^b	0.829
SBP (mmHg)			132(12)	138(22)	-2.504 ^b	< 0.012
DBP (mmHg)			78(9)	77(10)	-0.579 ^b	0.562
PT			11.10(1)	10.70(1)	-5.889 ^b	< 0.001
APTT			35.5(5)	20(14)	-14.214 ^b	< 0.001
TT			12(1)	12(2)	-4.841 ^b	< 0.001
FIB			3(1)	3.71(1)	-7.136 ^b	< 0.001
D-dimer			0.22(0.13)	0.34(0.29)	-11.150 ^b	< 0.001
FPG			4.89(1)	4.78(1)	-0.764 ^b	0.445
Note: a denotes chi-square test; b indicates the Mann–Whitney U test.; Abbreviations: HR, heart rate (bpm); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); FPG, fasting plasma glucose; PT, prothrombin time; APTT, activated partial thromboplastin time; TT, thrombin time; FIB, fibrinogen.						

Comparison of perioperative hypothermia between the MCVT and non-MCVT groups

Perioperative core temperature was categorised using a threshold of 36.0°C. As shown in Table 2, the distribution of perioperative hypothermia differed significantly between the MCVT and non-MCVT groups

at multiple time points, including before anaesthesia induction, at anaesthesia induction, 1h after anaesthesia induction, 2h after anaesthesia induction, at the end of surgery, and upon emergence from anaesthesia ($P < 0.001$). No statistically significant difference was observed 30 min after return to the ward.

A dynamic change in perioperative hypothermia was observed across the anaesthesia and surgical periods. In the MCVT group, the number of patients with core temperature $< 36.0^{\circ}\text{C}$ increased progressively from 2 before anaesthesia induction to 11 at anaesthesia induction, 27 at 1h after anaesthesia induction, and 68 at 2h after anaesthesia induction. Although the number decreased at the end of surgery and upon emergence from anaesthesia, the overall pattern suggested that hypothermia became more frequent during the prolonged anaesthesia period among patients who developed postoperative MCVT. These findings indicate that perioperative temperature changes, particularly the development and accumulation of hypothermic episodes during anaesthesia, may be associated with postoperative MCVT after total knee arthroplasty.

Table 2

Dynamic distribution of perioperative hypothermia in patients with and without postoperative MCVT

Variable	T (°C)	N (%)	Non-MCVT group (n = 741)	MCVT (n = 162)	χ^2/Z	P
CT ₋₁	<36°C	100(11.1)	98(13.2)	2(1.2)	19.409	< 0.001
	≥ 36°C	803(88.9)	643(86.8)	160(98.8)		
CT ₀	<36°C	408(45.2)	397(53.6)	11(6.8)	117.487	< 0.001
	≥ 36°C	495(54.8)	344(46.4)	151(93.2)		
CT _{1h}	<36°C	528(58.5)	501(67.6)	27(16.7)	142.087	< 0.001
	≥ 36°C	375(41.5)	240(32.4)	135(83.3)		
CT _{2h}	<36°C	643(71.2)	575(77.6)	68(42.0)	82.278	< 0.001
	≥ 36°C	260(28.8)	166(22.4)	94(58.0)		
CT _{end}	<36°C	556(61.6)	509(68.7)	47(29.0)	88.456	< 0.001
	≥ 36°C	347(38.4)	232(31.3)	115(71.0)		
CT _{emergence}	<36°C	459(50.8)	431(58.2)	28(17.3)	88.892	< 0.001
	≥ 36°C	444(49.2)	310(41.8)	134(82.7)		
CT _{30W}	<36°C	146(16.2)	117(15.8)	29(17.9)	0.437	0.508
	≥ 36°C	757(83.8)	624(84.2)	133(82.1)		

Note: Data are presented as n (%). Inadvertent perioperative hypothermia was defined as a core temperature < 36.0°C. MCVT, muscular calf vein thrombosis; CT, core temperature; CT₋₁, before anaesthesia induction; CT₀, at anaesthesia induction; CT_{1h}, 1 h after anaesthesia induction; CT_{2h}, 2h after anaesthesia induction; CT_{end}, end of surgery; CT_{emergence}, emergence from anaesthesia; CT_{30W}, 30 min after return to the ward. Comparisons between groups were performed using the chi-square test.

Variable coding and multivariable logistic regression analysis

Variable assignment

Variables that were statistically significant in the univariable analysis or considered clinically relevant were included in the multivariable logistic regression model. The assignment of independent variables is shown in Table 3.

Table 3
Variable coding for multivariable logistic regression analysis

Variable	Assignment Method	
Dependent variable: MCVT	1 = MCVT group	0 = non-MCVT group
Sex	1 = Male	0 = female
Occupation	Dummy variables were created, with farmer as the reference category	
Anticoagulant Use	1 = No	
CT ₋₁	1 = <36 °C	0 = ≥ 36 °C
CT ₀	1 = <36 °C	0 = ≥ 36 °C
CT _{1h}	1 = <36 °C	0 = ≥ 36 °C
CT _{2h}	1 = <36 °C	0 = ≥ 36 °C
CT _{se}	1 = <36 °C	0 = ≥ 36 °C
CT _{emer}	1 = <36 °C	0 = ≥ 36 °C
SBP (mmHg)	Actual measured value	
PT	Actual measured value	
APTT	Actual measured value	
TT	Actual measured value	
FIB	Actual measured value	
D-Dimer	Actual measured value	

Multivariable logistic regression analysis of factors associated with postoperative MCVT

Postoperative MCVT, diagnosed by bilateral lower-limb venous Doppler ultrasound, was used as the dependent variable in the multivariable logistic regression model. Variables that were statistically significant in the univariable analysis and clinically relevant variables were entered into the model using the Enter method. These variables included sex, occupation, standardised anticoagulant use, postoperative systolic blood pressure, prothrombin time, activated partial thromboplastin time, thrombin time, fibrinogen, D-dimer, and perioperative core temperature at different time points.

The overall logistic regression model was statistically significant ($\chi^2 = 39.066$, $P < 0.001$). The Nagelkerke R^2 value was 0.824, indicating that the model had a high level of explanatory performance. The Hosmer–Lemeshow goodness-of-fit test showed no evidence of poor model fit ($\chi^2 = 3.339$, $P = 0.911$).

As shown in Table 4, core temperature at anaesthesia induction, core temperature 1h after anaesthesia induction, core temperature upon emergence from anaesthesia, prothrombin time, activated partial thromboplastin time, thrombin time, fibrinogen, and D-dimer were independently associated with postoperative MCVT after total knee arthroplasty. Specifically, perioperative temperature categories at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia remained significantly associated with MCVT after adjustment for coagulation-related indicators and other covariates.

Table 4
Multivariable logistic regression analysis of factors associated with postoperative MCVT after total knee arthroplasty (n = 903)

Factors	β	SE	Wald χ^2	P	OR	(95%CI)
Constant	26.704	4.272	39.066	< 0.001	-	-
CT o	1.914	0.579	10.905	0.001	6.777	(2.177, 21.100)
CT _{1h}	1.245	0.438	8.087	0.004	3.474	(1.473, 8.193)
CT emer	0.944	0.451	4.393	0.036	2.571	(1.063,6.218)
PT	-1.620	0.246	43.457	< 0.001	0.198	(0.122,0.320)
APTT	-0.392	0.042	86.763	< 0.001	0.676	(0.622,0.734)
TT	-0.773	0.205	14.243	< 0.001	0.462	(0.309,0.690)
FIB	1.365	0.269	25.679	< 0.001	3.916	(2.310,6.639)
D-Dimer	11.154	1.884	35.045	< 0.001	69824.367	(1738.813,2803891.426)

Predictive performance of perioperative core temperature and coagulation-related indicators for postoperative MCVT

ROC curve analysis was performed to evaluate the predictive performance of perioperative core temperature and coagulation-related indicators for postoperative MCVT after total knee arthroplasty. The results are shown in Table 5 and Fig. 2.

Among the perioperative temperature indicators, core temperature 1h after anaesthesia induction showed the highest discriminative performance for postoperative MCVT, with an area under the curve (AUC) of 0.755 (95% CI: 0.725–0.782), a Youden index of 0.51, a sensitivity of 83.33%, and a specificity of 67.61%. Core temperature at anaesthesia induction also demonstrated moderate predictive performance, with an AUC of 0.734 (95% CI: 0.704–0.763), a sensitivity of 93.21%, and a specificity of 53.58%. Core temperature upon emergence from anaesthesia had an AUC of 0.704 (95% CI: 0.673–0.734), with a sensitivity of 82.72% and a specificity of 58.16%. These findings indicate that perioperative temperature at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia

may provide clinically useful information for identifying patients at increased risk of postoperative MCVT. Among these, core temperature 1h after anaesthesia induction showed the best overall balance between sensitivity and specificity.

The predictive performance of coagulation-related indicators varied across variables. Activated partial thromboplastin time showed the highest discriminative ability, with an AUC of 0.856 (95% CI: 0.831–0.878), a Youden index of 0.58, a sensitivity of 67.28%, and a specificity of 90.96%. D-dimer also showed moderate predictive performance, with an AUC of 0.779 (95% CI: 0.750–0.805), a sensitivity of 67.28%, and a specificity of 74.76%. Fibrinogen had modest predictive performance, with an AUC of 0.678 (95% CI: 0.647–0.709), whereas prothrombin time and thrombin time showed relatively limited discriminative ability, with AUCs of 0.647 (95% CI: 0.615–0.678) and 0.615 (95% CI: 0.583–0.647), respectively.

Overall, perioperative core temperature indicators demonstrated moderate predictive value for postoperative MCVT, particularly core temperature 1h after anaesthesia induction. However, activated partial thromboplastin time and D-dimer showed stronger discriminative performance than individual temperature indicators. These results suggest that perioperative temperature monitoring may be useful as an early warning indicator, whereas its predictive value may be further enhanced when interpreted together with coagulation-related parameters.

Table 5 Predictive performance of perioperative core temperature and coagulation-related indicators for postoperative MCVT					
Project	AUC (95%CI)	Youden index	Cut-off value	Sensitivity (%)	Specificity (%)
CT o	0.734(0.704~0.763)	0.47	1	93.21	53.58
CT 1h	0.755(0.725~0.782)	0.51	1	83.33	67.61
CT emer	0.704(0.673~0.734)	0.41	1	82.72	58.16
PT	0.647(0.615~0.678)	0.22	10.2	37.65	81.21
APTT	0.856(0.831~0.878)	0.58	29.4	67.28	90.96
TT	0.615(0.583~0.647)	0.16	11	35.80	79.89
FIB	0.678(0.647~0.709)	0.33	3.48	59.88	73.01
D-Dimer	0.779(0.750~0.805)	0.42	0.29	67.28	74.76

Discussion

Clinical relevance and incidence of postoperative MCVT after TKA

MCVT remains a clinically relevant thrombotic event after major orthopaedic surgery. In the present study, postoperative MCVT was detected in 162 of 903 patients who underwent TKA, corresponding to an incidence of 17.9%. Although MCVT is anatomically located in the distal venous system and is often considered less severe than proximal deep vein thrombosis, it should not be regarded as clinically negligible, particularly in postoperative orthopaedic patients.

Previous studies have reported variable incidences of calf venous thrombosis across different orthopaedic populations and assessment time points. In patients undergoing TKA, postoperative DVT has frequently been detected in distal calf veins and is often asymptomatic[15]. Chang et al. reported that a substantial proportion of patients developed DVT after TKA, most of which was distal and asymptomatic[16]. Similarly, Itou et al. found that postoperative DVT was detected in 34% of knees by duplex ultrasound on postoperative day 7, and soleal vein thrombus accounted for 74.6% of DVT cases[17]. In addition, Pan et al. reported a high preoperative prevalence of calf muscular vein thrombosis among elderly patients with hip fractures, suggesting that immobilisation, frailty, and fracture-related physiological stress may contribute to differences in MCVT prevalence across orthopaedic populations[18]. These findings support the view that calf venous thrombosis, particularly thrombosis involving the soleal or muscular calf veins, is common after TKA and may be under-recognised if routine imaging is not performed.

The incidence observed in the present study was lower than that reported in some previous TKA cohorts, but it still indicates that MCVT is not uncommon after TKA. Differences in reported incidence may be partly explained by variations in patient populations, imaging modalities, timing of ultrasound or venographic assessment, perioperative anticoagulation strategies, mobilisation protocols, and definitions of MCVT. By contrast, hip fracture patients are often older, more frail, and more likely to experience preoperative immobilisation, which may contribute to a higher prevalence of calf muscular vein thrombosis before surgery. The present study focused on postoperative MCVT after TKA, a setting in which perioperative factors such as anaesthesia-related temperature changes, thromboprophylaxis, surgical trauma, postoperative pain, swelling, and early rehabilitation may all influence thrombus formation and detection.

The clinical presentation of MCVT after TKA may also be subtle. Postoperative pain, swelling, and limited mobility are common after knee arthroplasty and may overlap with, or mask, symptoms of calf venous thrombosis. Consequently, relying solely on clinical symptoms may lead to under-recognition or delayed diagnosis. Given the relatively high incidence observed in this cohort and the potential for thrombus progression or concomitant thromboembolic events reported in previous studies, postoperative surveillance of MCVT should receive greater attention in patients undergoing TKA. In this context, early identification of patients at increased risk of MCVT may help guide targeted Doppler ultrasound surveillance, optimisation of thromboprophylaxis, and timely rehabilitation strategies.

Perioperative hypothermia as a potential early warning indicator for postoperative MCVT

Perioperative hypothermia may serve as a clinically accessible and potentially modifiable early warning indicator for postoperative MCVT after TKA. The biological plausibility of this association is supported by the well-established effects of anaesthesia on thermoregulation. Under normal physiological conditions, body temperature is maintained through coordinated central thermoregulatory control, peripheral temperature sensing, vasoconstriction, shivering, and behavioural responses. However, both general and neuraxial anaesthesia impair these protective mechanisms by reducing thermoregulatory thresholds, promoting peripheral vasodilation, and redistributing heat from the core compartment to peripheral tissues. This redistribution effect is particularly prominent during the early phase after anaesthesia induction and may explain why core temperature often decreases within the first hour of anaesthesia[19].

In the present study, perioperative temperature disturbance was observed across several anaesthesia-related time points, including before anaesthesia induction, at anaesthesia induction, 1h and 2h after anaesthesia induction, at the end of surgery, and upon emergence from anaesthesia. More importantly, multivariable logistic regression showed that core temperature at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia remained independently associated with postoperative MCVT after adjustment for coagulation-related indicators and other covariates. ROC curve analysis further demonstrated that these three temperature indicators had moderate predictive performance, with core temperature 1h after anaesthesia induction showing the highest discriminative ability among the temperature-related variables. This finding is clinically meaningful because the first hour after anaesthesia induction may represent a critical window during which redistribution hypothermia, ongoing heat loss, surgical exposure, and impaired thermoregulatory defence occur simultaneously.

The association between perioperative hypothermia and postoperative venous thrombosis is also supported by previous clinical evidence. Li et al. found that intraoperative hypothermia was independently associated with postoperative deep vein thrombosis after intracranial tumour resection, suggesting that perioperative temperature disturbance may be related to postoperative venous thrombotic events[20]. Although their study population and thrombotic endpoint differed from those of the present study, their findings support the clinical plausibility of a relationship between perioperative hypothermia and postoperative thrombosis. The present study extends this evidence to patients undergoing TKA by focusing specifically on postoperative MCVT and by evaluating the predictive value of temperature measurements at multiple perioperative time points.

The clinical relevance of emergence-period temperature should also be noted. Hypothermia during anaesthesia recovery may reflect cumulative intraoperative heat loss, prolonged operative exposure, infusion of unwarmed fluids, blood loss, and insufficient active warming before emergence from anaesthesia. Liu and Qi reported that older age, greater intraoperative infusion volume, increased blood loss, major surgery, and longer operative duration were associated with hypothermia during the anaesthesia recovery period, and that active warming improved thermal recovery compared with

conventional warming methods[21]. These findings support the importance of continuous temperature monitoring not only during surgery but also during recovery from anaesthesia.

From a clinical implementation perspective, perioperative temperature is particularly valuable because it is routinely available, continuously measurable, and potentially modifiable. A multidisciplinary consensus study on perioperative hypothermia prevention recommended active core temperature monitoring for all patients throughout perioperative care, active warming to maintain body temperature above 36°C, and minimisation of cold exposure at all perioperative stages[22]. However, translation into practice remains challenging. Oden et al. reported that perioperative health care professionals had only moderate knowledge of evidence-based inadvertent perioperative hypothermia management, and that only a minority correctly identified < 36°C as the threshold for inadvertent perioperative hypothermia[23]. These findings suggest that temperature-based risk identification requires not only statistical validation but also standardised perioperative protocols, staff education, and multidisciplinary implementation.

Therefore, the present findings should be interpreted as evidence that perioperative temperature may contribute to early MCVT risk stratification after TKA. Temperature indicators should not replace Doppler ultrasound for the diagnosis of MCVT, but they may help identify patients who require closer postoperative thrombotic surveillance, optimisation of thromboprophylaxis, and timely rehabilitation. Maintaining perioperative normothermia may be a practical component of comprehensive MCVT prevention, although prospective studies are needed to determine whether active warming interventions can directly reduce postoperative MCVT after TKA.

Clinical implications for perioperative temperature management

The findings of this study suggest that perioperative temperature management may have clinical relevance for postoperative MCVT prevention after TKA. Unlike many non-modifiable thrombotic risk factors, perioperative hypothermia is routinely measurable and potentially preventable. Previous recommendations have emphasised that core temperature should be monitored throughout the perioperative period and that active warming should be used to maintain body temperature above 36°C[19, 22]. These recommendations are consistent with the present finding that temperature at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia were independently associated with postoperative MCVT.

For patients undergoing TKA, perioperative temperature monitoring should therefore not be regarded merely as routine vital-sign recording. Instead, abnormal temperature changes, particularly during early anaesthesia and emergence from anaesthesia, may help identify patients who require closer postoperative thrombotic surveillance. This is clinically important because postoperative pain, swelling, and limited mobility after TKA may obscure the early manifestations of MCVT. In addition, recovery-period hypothermia has been associated with older age, greater infusion volume, increased blood loss, major surgery, and longer operative duration, suggesting that emergence temperature may reflect the cumulative physiological burden of surgery and anaesthesia [21].

Therefore, maintaining perioperative normothermia may be considered a practical component of comprehensive MCVT risk management after TKA. However, temperature management should not be interpreted as a substitute for standard thromboprophylaxis or Doppler ultrasound diagnosis. Rather, perioperative temperature indicators may be used together with coagulation-related markers, early mobilisation, and targeted ultrasound surveillance to support early risk identification. Future prospective studies are needed to determine whether standardised active warming interventions can reduce the incidence of postoperative MCVT in patients undergoing TKA.

Limitations

This study has several limitations. First, this was a single-centre retrospective cohort study, and selection bias and residual confounding cannot be fully excluded. Although multivariable regression was performed, some perioperative factors, including anaesthesia type, operative duration, blood loss, infusion volume, warming methods, tourniquet use, postoperative pain, and early mobilisation, were not comprehensively analysed. Second, postoperative MCVT was diagnosed using bilateral lower-limb Doppler ultrasound, but the timing of ultrasound assessment may have varied according to clinical workflow, which could have influenced the observed incidence. Third, perioperative temperature was assessed at predefined time points, whereas the cumulative burden of hypothermia, such as duration below 36.0°C and consecutive hypothermic episodes, was not evaluated. Future prospective studies incorporating continuous temperature monitoring are needed to further clarify the relationship between hypothermic exposure and postoperative MCVT after TKA.

Conclusion

This study demonstrated that postoperative MCVT is a common thrombotic event after TKA, with an incidence of 17.9% in this cohort. Perioperative hypothermia, particularly core temperature at anaesthesia induction, 1h after anaesthesia induction, and emergence from anaesthesia, was independently associated with postoperative MCVT. Among these temperature indicators, core temperature 1h after anaesthesia induction showed the best predictive performance. These findings suggest that perioperative temperature changes may provide a practical basis for early risk identification and targeted postoperative surveillance. Strengthened temperature monitoring and maintenance of perioperative normothermia may contribute to comprehensive MCVT prevention after TKA. Further prospective studies are needed to validate these findings and clarify whether active warming strategies can reduce postoperative MCVT risk.

Abbreviations

IPH Inadvertent perioperative hypothermia

MCVT Muscular calf vein thrombosis

DVT Deep vein thrombosis

TKA Total knee arthroplasty

ROC Receiver operating characteristic

AUC Area under the curve

BMI Body mass index

ICD-10 International Classification of Diseases, Tenth Revision

SPSS Statistical Package for the Social Sciences

Declarations

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Not applicable.

Author Contributions

J.L., Y.C., S.W., P.L. and M.Z. were involved in the conception and design of the study. J.L., Y.C., R.C. and P.L. contributed to data analysis and interpretation. Y.L.C., L.C., S.W., Y.W. and Y.Z. were responsible for data collection. J.L. drafted the manuscript. Y.C., Y.L.C., R.C. and L.C. critically revised the manuscript for important intellectual content. J.L., Y.C., S.W. and R.C. performed the statistical analysis. P.L. obtained funding and provided overall responsibility for the study. All authors read and approved the final manuscript.

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Ethics approval and consent to participate

The authors declare no competing interests.

Clinical trial number:

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Ethical Compliance

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study has been approved by the Ethics Committee of Luoyang Orthopedic Hospital (Henan Orthopedic Hospital) (Ethics Approval Number: KY2023-012-01).

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Figures

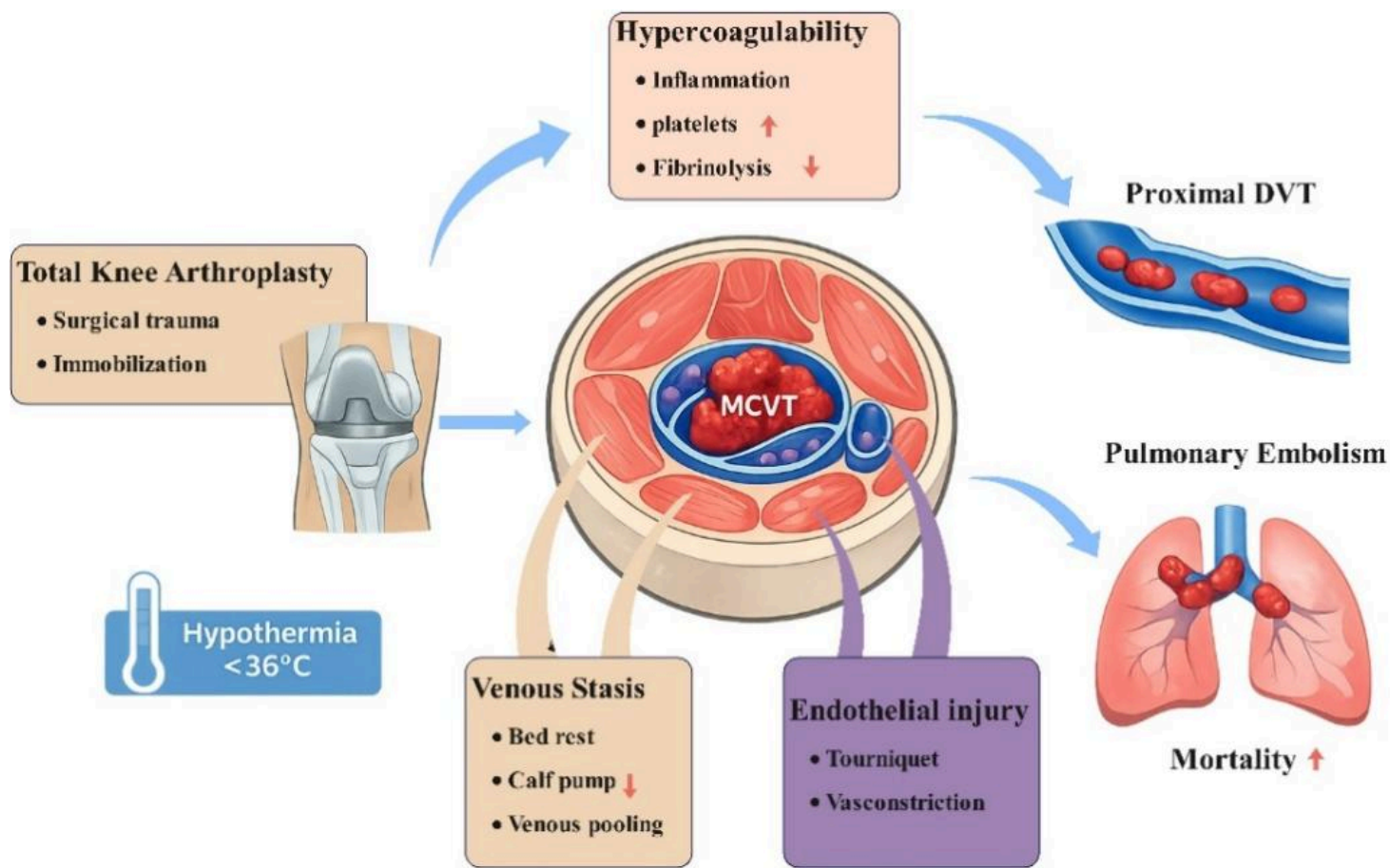


Figure 1

Proposed mechanisms linking perioperative hypothermia to postoperative MCVT after TKA

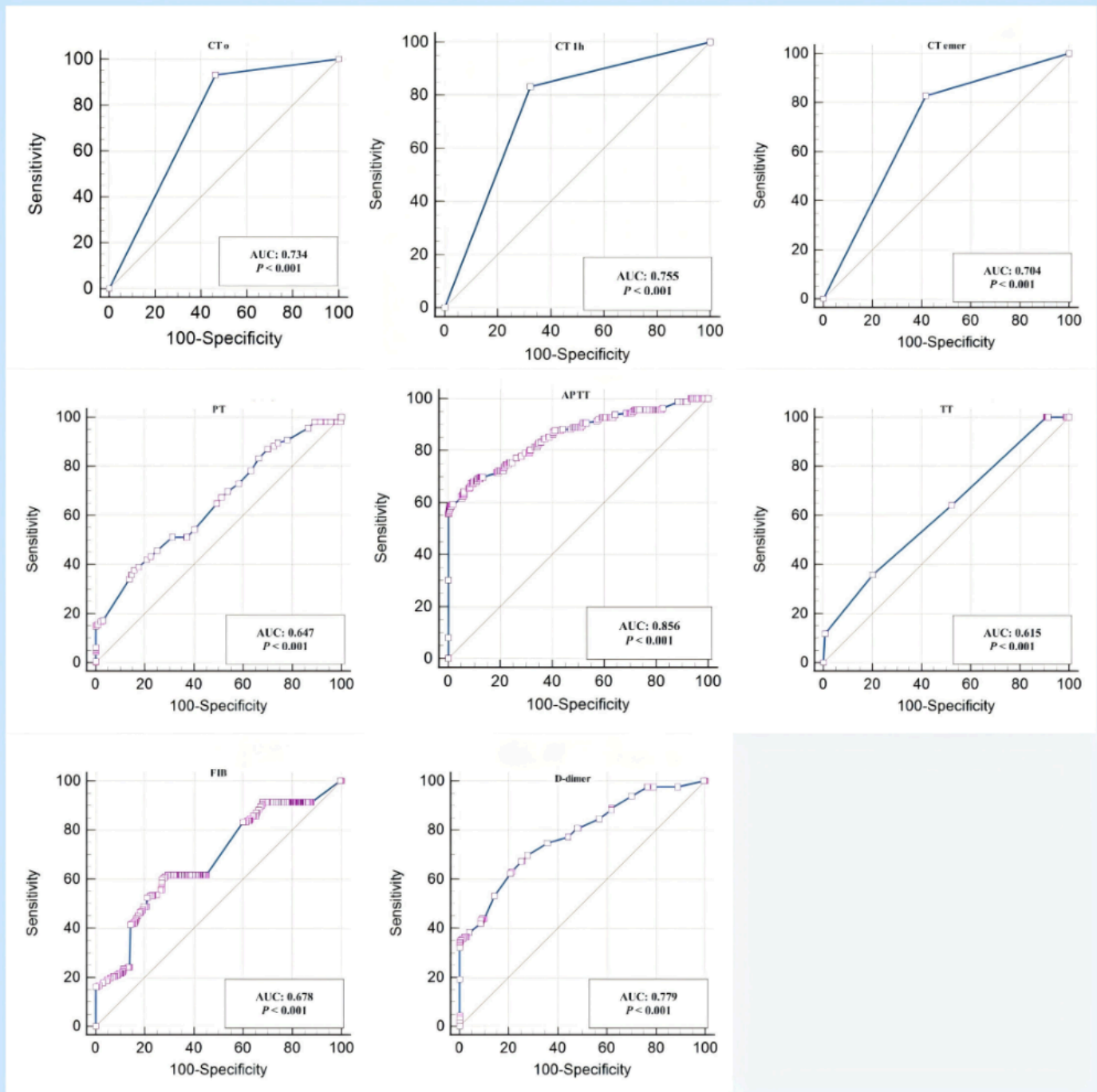


Figure 2

Receiver operating characteristic curves for predictors of postoperative MCVT.