Case-Controlled Study

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Correlation between the preoperative maximum soleal vein diameter and the postoperative bilateral deep venous thrombosis in THA: a case–control study

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Background: Patients with bilateral lower limb deep venous thrombosis (DVT) have a higher risk of pulmonary thromboembolism (PTE) and mortality than patients with unilateral lower limb DVT. Preoperative dilatation of the soleal vein (SV) diameter is a predictor of postoperative DVT. The purpose of this study is to investigate the cutoff value for SV diameter as a risk factor for VTE development.
Materials and methods: The authors examined 274 patients with unilateral THA who met the inclusion criteria in a retrospective study. The mean age of the patients was 65.7 ± 11.2 years, with 70 males and 204 females. Bilateral lower limb vein ultrasonography was performed preoperatively and ~1 week after THA. The frequency and localization of DVT were investigated in postoperative ultrasonography. The patients were divided into three groups: no DVT (non-DVT), unilateral lower limb DVT (Uni-DVT), and bilateral lower limb DVT (Bi-DVT). The three groups were compared in terms of preoperative venous vessel maximum diameter.
Results: There were 62 patients (22.6%) who had postoperative DVT. There are no symptomatic PTE patients. DVT was found in 44 patients (16.0%) of the Uni-DVT group and 18 patients (6.6%) of the Bi-DVT group. The SV maximum diameter was 6.41 ± 1.79 mm in the non-DVT group, 7.06 ± 2.13 mm in the Uni-DVT group, and 8.06 ± 2.26 mm in the Bi-DVT group, with a significant difference ($P = 0.001$) between the non-DVT and Bi-DVT groups. In the Bi-DVT group, the cutoff value for preoperative SV maximum diameter was 6.75 mm (95% CI: 0.625–0.831; $P = 0.001$; sensitivity, 77.8%; specificity, 60.4%; area under the curve, 0.728).
Conclusions: In THA, preoperative ultrasonography with a maximum SV diameter of 6.75 mm or greater was the risk of bilateral DVT leading to fatal PTE is increased.

Keywords: deep venous thrombosis, postoperative complications, total hip arthroplasty, ultrasonography

Introduction

In Japan, the number of total hip arthroplasty (THA) procedures is increasing year after year[1]. Even in the early postoperative period, THA improves hip function and activity of daily living (ADL), and patient satisfaction is high. However, according to the American College of Chest Physicians guidelines, the baseline risk of symptomatic venous thromboembolism (VTE) associated with major orthopedic surgery (THA, total knee arthroplasty (TKA), hip fracture surgery) is 4.5% (symptomatic deep venous thrombosis (DVT), 2.8%; PTE, 1.5%). Furthermore, even when low molecular weight heparin is used as a drug prophylaxis, the risk of symptomatic VTE remains 1.8% (symptomatic DVT, 1.25%; PTE, 0.55%)[2]. Moreover, the risk of fatal PTE after THA or TKA is ~0.05%[3,4]. Despite its rarity, PTE is undoubtedly a significant cause of perioperative death following THA. Although further reduction of fatal PTE is desirable, postoperative routine ultrasonography for asymptomatic DVT is not recommended in several guidelines due to efficacy[5,6]. Therefore, it is important to extract DVT risk factors without postoperative ultrasonography.

HIGHLIGHTS

- Preoperative dilatation of the soleal vein correlates with postoperative bilateral lower limb deep venous thrombosis.
- The cutoff value for preoperative soleal vein maximum diameter is 6.75 mm.
- In hip arthroplasty, preoperative ultrasonography with a maximum SV diameter of 6.75 mm or greater should be considered postoperative ultrasonography.

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Patients with DVT in bilateral lower limbs have a higher risk of PTE and a higher mortality rate than those with DVT in only unilateral limb[7,8]. Dilatation of the soleal vein (SV), the preferred site for DVT, has been associated with acute PTE[9]. Furthermore, preoperative SV dilatation has been reported to be a predictor of postoperative DVT development[10,11]. These findings suggest that patients with SV dilation are more likely to develop fatal PTE. The purpose of this study is to investigate the cutoff value for SV diameter as a risk factor for VTE development.

Materials and methods

Study design

This was a case–control, single-center study. Inclusion criteria were patients who visited our hospital and underwent THA from May 2017 to April 2020. We excluded patients because DVT was detected on preoperative ultrasonography, and who could not take the limb position to measure venous vessel diameter. Furthermore, we only assessed the first side of patients who received bilateral THA during the study period. This study was approved by the Institutional Review Board of our institution, which was carried out in accordance with the Helsinki Declaration, and was written in line with the STROCSS statement[12]. This study was registered with the Research Registry. Informed consent was not required because this is a case–control study.

Patients

We examined the records of patients who visited our hospital from May 2017 to April 2020. We then performed unilateral THA on 353 patients with hip pain, 274 of whom were enrolled in this study. However, we excluded 56 patients because DVT was detected on preoperative ultrasonography, as well as 23 patients who could not take the limb position to measure venous vessel diameter. Furthermore, we only assessed the first side of patients who received bilateral THA during the study period. The mean age of the patients was 65.7 ± 11.2 (range, 27–92) years, with 70 males and 204 females. There were 215 with osteoarthritis, 40 with osteonecrosis, 16 with rheumatoid arthritis, and 3 with a femoral neck fracture. The details of the demographic characteristics of patients with THA are presented in Table 1.

Table 1

Demographic characteristics of patients with THA.

Variables	All patients ($n = 274$)
Age (years)	65.7 ± 11.2
Sex (male/female)	70/204
BMI (kg/m^2)	24.5 ± 4.1
Operation time (min)	109.6 ± 32.9
Intraoperative bleeding volume (ml)	306.0 ± 187.6
Postoperative pharmacological prophylaxis	264
Diagnosis of THA	
Osteoarthritis of the hip	215
Osteonecrosis	40
Rheumatoid arthritis	16
Femoral neck fracture	3
Medical history	
Hypertension	92
Diabetes mellitus	32
Dyslipidemia	27
Heart disease	12
Arrhythmia	9
Malignancy	14
Stroke	8
Hepatitis, cirrhosis	11
Respiratory disease	18
Kidney disease	15
Thyroid disease	11
Vasculitis	5
Connective tissue disease	28
Hematological disease	6
Past history of THA or TKA	21
Corticosteroids	24

Data are shown as mean ± SD or number. THA, total hip arthroplasty; TKA, total knee arthroplasty.

Surgical information and postoperative protocols

Under general anesthesia, four orthopedic specialists performed unilateral THA in the lateral decubitus position. We used the mini-one anterior lateral approach[13] in 262 hips, and in 12 hips, we used the conjoined tendon preserving posterior approach[14]. The shells were fitted in 272 hips using a cementless procedure or in 2 hips using a cemented procedure. In 270 hips, the stem was fitted using a cementless procedure, while 4 hips were fitted using a cemented procedure. The average operation time was 109.6 ± 32.9 (range, 63–296) min. On the other hand, the average intraoperative bleeding volume was 306 ± 187.6 (range, 42–1216) ml (Table 1).

Immediately after the surgery, the patient wore elastic compression stockings, intermittent pneumatic compression was applied, and active ankle movements were initiated. The patient jumped out of bed the next morning and started walking practice as soon as possible. The day after surgery, a prophylactic anticoagulant was started to prevent VTE. There were 189 patients prescribed with edoxaban at the recommended dose of 30 mg/day, and 54 patients prescribed 15 mg/day adjusted for age, body weight, and renal function. Due to comorbidity, 21 patients used other anticoagulants or antiplatelet drugs before surgery (clopidogrel sulfate, 6 patients; apixaban, 4 patients; warfarin sodium, 3 patients; aspirin, 3 patients; rivaroxaban, 2 patients; cilostazol, 2 patients; ticlopidine hydrochloride, 1 patient). Prophylactic anticoagulant was not given to seven dialysis patients and three liver cirrhotic patients.

Ultrasonography

Ultrasonography were obtained using the Aplio MX (CANON Medical Systems Corporation), the Prosound F75 (FUJIFILM Healthcare Corporation), and the ARIETTA 850 (FUJIFILM Healthcare Corporation) with the linear probe.

Bilateral lower limb vein ultrasonography was performed preoperatively and postoperatively 1 week after THA. A medical technologist (MT) performed the ultrasonography, another MT confirmed the results. Moreover, the report is finally approved by the cardiologist.

The femoral vein, superficial femoral vein, deep femoral vein, popliteal vein, peroneal vein, anterior tibial vein, posterior tibial vein, SV, large saphenous vein, and small saphenous vein were all examined. In the supine position, we checked the thigh, while in the sitting position, we checked the lower leg beyond the popliteal vein. Thrombus screening was performed in B mode using the

compression and Doppler methods. When an intravenous thrombus image and intravascular noncompression findings were observed, a thrombus-positive diagnosis was made when an intravenous thrombus image and intravascular noncompression findings were observed[15].

Evaluation methods

The frequency and localization of DVT were investigated in postoperative ultrasonography. Based on the presence of DVT, patients were divided into three groups: no DVT (non-DVT), unilateral lower limb DVT (Uni-DVT), and bilateral lower limb DVT (Bi-DVT) group. The three groups were compared on age, sex, BMI, medical history, operative time, intraoperative blood loss, preoperative blood laboratory data (TP, Alb, CPK, AST, ALT, LDH, Cr, BUN, eGFR, Na, Cl, K, T-bil, CRP, APTT, PT-INR, D-dimer, WBC, Hb, PLT), and preoperative venous vessel maximum diameter.

Statistical analysis

All data were analyzed using the SPSS ver.26. As statistical methods, the Student's *t*-test and Mann–Whitney *U*-test were performed on continuous variables. Categorical variables were subjected to the χ^2 and Fisher's exact test. The one-way ANOVA test was used to make the comparison between the three groups. The sensitivity and specificity of DVT onset prediction were calculated by the threshold value from the receiver operator characteristic (ROC) curve. $P < 0.05$ was deemed significant.

Results

Among the 274 patients, 62 (22.6%) patients had DVT after surgery. There were 61 cases of distal DVT and one case of proximal DVT. There was no patient with symptomatic PTE. Moreover, DVT was found in the unilateral lower limb of 44 (16.0%) cases and in the bilateral lower limbs of 18 (6.6%) cases (Table 2).

There was no statistically significant difference in patient background or preoperative blood laboratory data between the non-DVT, Uni-DVT, and Bi-DVT groups (Tables 3 and 4). Table 5 shows the comparison results of preoperative ultrasonographic data among the three groups. The preoperative SV maximum diameter differed significantly, but the other vessel diameters did not differ significantly. The SV maximum diameter was 6.41 ± 1.79 (range, 2.5–12.3) mm in the non-DVT group, 7.06 ± 2.13 (range, 3–12.4) mm in the Uni-DVT group, and 8.06 ± 2.26 (range, 5.6–14.3) mm in the Bi-DVT group. Furthermore, a significant difference was observed between the non-DVT and Bi-DVT groups ($P = 0.001$) (Fig. 1). In the Bi-DVT group, the cutoff value for the preoperative SV maximum diameter was 6.75 mm[95% CI, 0.625–0.831; $P = 0.001$; sensitivity, 77.8%; specificity, 60.4%; and area under the curve (AUC), 0.728] (Fig. 2).

Table 2

Localization of DVT.

Vessels	DVT group ($n = 62$)
Uni-DVT	44
SV	39
PEV	2
PV	1
SV + PTV	1
FV + PV + PTV + PEV + ATV + SV	1
Bi-DVT	18
Bi-SV	16
Bi-SV + Uni-PEV	1
Bi-SV + Uni-PTV + Uni-PEV	1

ATV, anterior tibial vein; Bi, bilateral; DVT, deep venous thrombosis; FV, femoral vein; PEV, peroneal vein; PTV, posterior tibial vein; PV, popliteal vein; SV, soleal vein; Uni, unilateral.

Table 3

Demographic characteristics of patients with THA (non-DVT group vs. Uni-DVT group vs. Bi-DVT group).

Variables	non-DVT group ($n = 212$)	Uni-DVT group ($n = 44$)	Bi-DVT group ($n = 18$)	*P*
Age (years)	65.1 ± 11.7	67.6 ± 8.8	68.1 ± 8.9	0.186
Sex (male/female)	58/154	9/35	3/15	0.425
BMI (kg/m^2)	24.6 ± 4.4	23.8 ± 3.0	25.3 ± 3.5	0.380
Operation side (rt/lt)	119/93	22/22	8/10	0.517
Operation time (min)	110.6 ± 32.6	105.6 ± 30.2	108.0 ± 42.9	0.643
Intraoperative bleeding volume (ml)	314.4 ± 194.7	280.7 ± 164.5	268.8 ± 149.4	0.381
Postoperative pharmacological prophylaxis	203	43	18	0.568
Medical history				
Hypertension	69	16	7	0.786
Diabetes mellitus	25	7	0	0.207
Dyslipidemia	21	5	1	0.784
Heart disease	11	1	0	0.444
Arrhythmia	6	1	2	0.153
Malignancy	11	2	1	0.981
Stroke	5	1	2	0.153
Hepatitis, cirrhosis	8	3	0	0.431
Respiratory disease	14	4	0	0.423
Kidney disease	10	4	1	0.510
Thyroid disease	9	1	1	0.784
Vasculitis	3	1	1	0.439
Connective tissue disease	23	5	0	0.332
Hematological disease	5	1	0	0.806
Past history of THA or TKA	16	4	1	0.885
Corticosteroids	18	5	1	0.732

Data are shown as mean ± SD or number. THA total hip arthroplasty; DVT, deep venous thrombosis; Uni, unilateral; Bi, bilateral; TKA, total knee arthroplasty.

Discussion

According to Fürbringer-Schwarz *et al.*[7] patients with bilateral DVT has a significantly higher clinical risk of mortality than patients with unilateral DVT ($P = 0.002$). Moreover, according to El-Menyar *et al.*[8] rates of PTE (left 10%, right 13.2%, bilateral 25% ($P = 0.008$)) and mortality (left 11.7%, right 17.9%, bilateral 23.1% ($P = 0.02$)) were significantly higher in the bilateral DVT group than in the left-sided and right-sided DVT groups. It has also been reported that 89% of PTE autopsy cases had bilateral DVT, and all patients had DVT within the SV[16].

A few percent of patients experience bilateral DVT following THA surgery. Irie *et al.*[17] reported DVT in 33 of 208 cases using whole-leg ultrasonography, with 9 cases (4.3%) being bilateral.

Table 4

Preoperative blood laboratory data of patients with THA (non-DVT group vs. Uni-DVT group vs. Bi-DVT group).

Variables	non-DVT group ($n=212$)	Uni-DVT group ($n=44$)	Bi-DVT group ($n=18$)	P
Total protein (g/dl)	7.01 ± 0.54	7.10 ± 0.41	7.16 ± 0.50	0.311
Albumin (g/dl)	4.05 ± 0.40	4.03 ± 0.38	4.12 ± 0.42	0.714
CPK (U/l)	92.5 ± 63.0	98.6 ± 74.0	104.2 ± 58.1	0.679
AST (U/l)	23.0 ± 12.9	21.3 ± 6.65	23.2 ± 6.92	0.683
ALT (U/l)	18.6 ± 10.4	16.6 ± 9.33	21.2 ± 9.93	0.243
LDH (U/l)	201.2 ± 41.8	200.2 ± 33.5	200.9 ± 30.2	0.988
Creatinine (mg/dl)	0.85 ± 1.11	0.73 ± 0.45	0.66 ± 0.16	0.604
BUN (mg/dl)	16.8 ± 7.76	16.0 ± 6.49	16.7 ± 6.05	0.838
eGFR (ml/min/1.73 m^2)	75.0 ± 22.2	75.6 ± 22.0	74.8 ± 16.2	0.984
Na (mEq/l)	141.6 ± 2.34	142.1 ± 2.69	141.6 ± 1.42	0.503
Cl (mEq/l)	104.8 ± 2.66	104.8 ± 2.53	104.2 ± 2.16	0.702
K (mEq/l)	4.14 ± 0.38	4.08 ± 0.39	4.18 ± 0.40	0.575
CRP (mg/dl)	0.38 ± 1.38	0.52 ± 0.85	0.54 ± 1.65	0.753
APTT (sec)	29.2 ± 4.63	30.8 ± 10.7	30.2 ± 7.61	0.261
PT-INR	0.97 ± 0.09	0.98 ± 0.15	1.04 ± 0.43	0.619
D-dimer (μg/ml)	1.46 ± 1.63	1.98 ± 3.01	1.41 ± 1.75	0.247
WBC ($\times 10^3$/μl)	6.11 ± 1.72	5.98 ± 1.75	5.55 ± 1.15	0.389
Hemoglobin (g/dl)	12.6 ± 1.33	12.5 ± 1.17	13.2 ± 1.41	0.140
PLT ($\times 10^3$/μl)	271.2 ± 77.8	271.9 ± 74.0	256.0 ± 43.4	0.411

Data are shown as mean ± SD.

ALT, alanine aminotransferase; APTT, activated partial thrombin time; AST, aspartate aminotransferase; Bi, bilateral; BUN, blood urea nitrogen; Cl, chloride; CPK, creatine phosphokinase; CRP, c-reactive protein; DVT, deep venous thrombosis; eGFR, estimated glomerular filtration rate; INR, international normalized ratio; K, potassium; LDH, lactate dehydrogenase; Na, sodium; PT, prothrombin time; THA, total hip arthroplasty; Uni, unilateral; WBC, white blood cell count; PLT, platelet count.

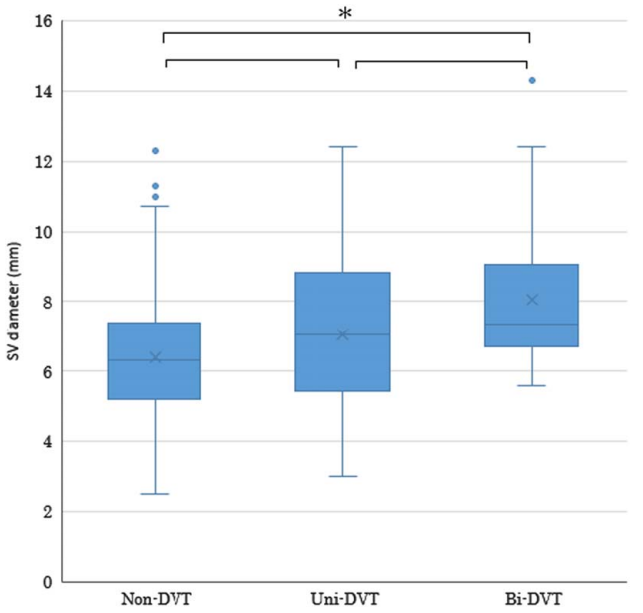

Figure 1. Comparison of SV diameter of THA patients (non-DVT group vs. Uni-DVT group vs. Bi-DVT group) *$P=0.001$. SV, soleal vein; THA, total hip arthroplasty; DVT, deep venous thrombosis; Uni, unilateral; Bi, bilateral.

In addition, Mant *et al.*[18] reported DVT in 2.1% (4 of 188 patients) with venography. In this study, DVT was found in 6.6% (18 out of 274) of patients using whole-leg ultrasonography, which was consistent with previous reports. Therefore, it is critical to identify risk factors for bilateral DVT and efficiently screen these cases.

A few reports have found a link between preoperative SV diameter and the occurrence of postoperative DVT in THA and TKA. Due to the anatomical characteristics of the SV, SV dilatation may be a risk factor for the development of postoperative DVT: (1) Since SV is only involved in ankle motion, prolonged supine or seated position can easily cause venous stasis. (2) Venous turbulence is caused by peripheral veins flowing into the central veins from multiple directions. (3) Because the central veins lack venous valves, they are prone to stasis and dilation when the valves fail. The pumping action of the soleus muscles in response to walking load normally maintains blood flow. Due to the decline in ADL prior to THA surgery, the lower limb muscles, especially the soleus muscles, may weaken their pumping function. This causes blood stagnation, which may have resulted in dilation of the vessel diameter, a precursor stage for DVT.

Abe *et al.*[10] reported that 67% of preoperative SV-dilated patients developed postoperative DVT, with all DVT occurring in the SV. Yao *et al.* used ultrasonography to measure the preoperative SV diameter in 402 THA and TKA patients and reported that the DVT group had a predominantly dilated preoperative SV diameter compared to the non-DVT group: postoperative DVT group 7.0 ± 2.7 mm and postoperative non-DVT group 5.3 ± 2.1 mm ($P<0.001$). Furthermore, dilatation of preoperative SV diameter was an independent risk factor for symptomatic DVT (OR, 10.27; 95% CI: 1.51–69.67; $P=0.017$)[11]. In our study, the SV diameter was 6.41 ± 1.79 mm in the non-DVT group, 7.06 ± 2.13 mm in the Uni-DVT group, or 8.06 ± 2.26 mm in the Bi-DVT group, with a significant difference between the non-DVT and Bi-DVT groups ($P=0.001$). This result showed that bilateral DVT cases, which are thought to be at higher risk of PTE, had significantly greater SV dilatation even before surgery.

Table 5

Preoperative ultrasonographic data of patients with THA (non-DVT group vs. Uni-DVT group vs. Bi-DVT group).

Variables	non-DVT group ($n=212$)	Uni-DVT group ($n=44$)	Bi-DVT group ($n=18$)	P
ATV diameter (mm)	3.36 ± 0.87	3.23 ± 0.99	3.47 ± 0.89	0.581
PTV diameter (mm)	4.48 ± 1.40	4.24 ± 1.28	4.60 ± 1.22	0.505
PEV diameter (mm)	5.80 ± 1.65	5.55 ± 1.76	6.07 ± 1.27	0.482
SV diameter (mm)	6.41 ± 1.79	7.06 ± 2.13	8.06 ± 2.26	**0.001***

*significant difference.

Data are shown as mean ± SD.

ATV, anterior tibial vein; Bi, bilateral; DVT, deep venous thrombosis; PEV, peroneal vein; PTV, posterior tibial vein; SV, soleal vein; THA, total hip arthroplasty; Uni, unilateral.

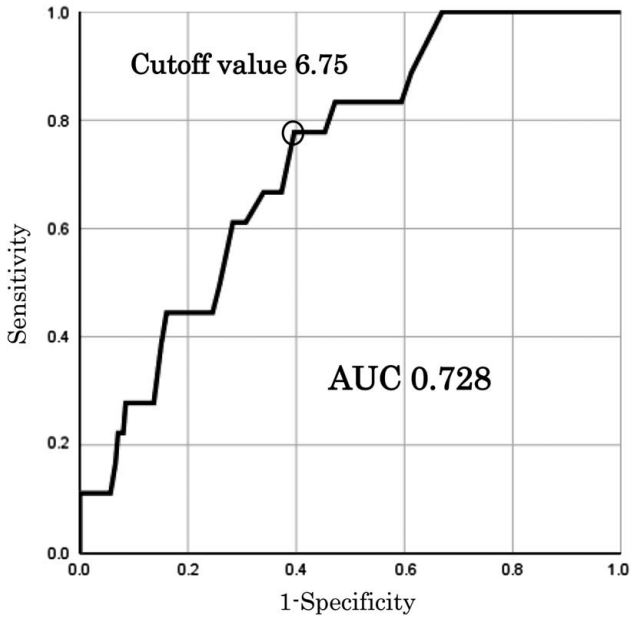

Figure 2. ROC analysis for SV diameter of the Bi-DVT group. AUC, area under the curve; ROC, receiver operator characteristic; SV, soleal vein; Bi, bilateral; DVT, deep venous thrombosis.

Only a few reports on SV diameters as efficient screening exist. Ohgi *et al*.[9] reported that the maximum diameter of the SV was 7 mm or greater in all eight cases of symptomatic PE. Abe *et al*.[10] reported that preoperative SV dilatation (>10 mm) was an independent predictor of the occurrence of postoperative DVT. However, there was no information on cutoff values for SV maximum diameter in the occurrence of bilateral DVT. We report that the cutoff value of the preoperative SV maximum diameter was 6.75 mm (95% CI: 0.625–0.831; $P=0.001$; sensitivity, 77.8%; specificity, 60.4%; and AUC, 0.728) (Fig. 2). Postoperative DVT screening by lower limbs ultrasonography should be considered in patients with a maximum SV diameter more than 6.75 mm before surgery.

There were several limitations to our study. First and foremost, this was a retrospective study. Second, because the patients were all Japanese, there may be differences between ethnic groups. Third, three different models were used for lower limb venous ultrasonography, while the MT was not the same for all patients. However, this may not have affected the results significantly. Though the ultrasonography was performed by a medical MT, the results were confirmed by another MT. Moreover, the cardiologist approved the report. Finally, because of the small sample size, the lack of statistical significance in the difference between groups may vary.

Conclusions

In THA, preoperative ultrasonography with a maximum SV diameter of 6.75 mm or greater was the risk of bilateral DVT leading to fatal PTE is increased.

Ethical approval

This study was approved by the Institutional Review Board of Saitama Medical University Hospital (No.20035).

Consent

Since this was a retrospective study, the requirement for informed consent from the study participants was waived by the Institutional Review Board of Saitama Medical University Hospital (No.20035).

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None.

Author contribution

F.K.: acquisition of data, analysis of data, drafting of the manuscript, critical analysis and revision, final approval; K.W.: acquisition of data, analysis of data, drafting of the manuscript, critical revision, final approval, corresponding author; N.O.: acquisition of data, final approval; T.M.: acquisition of data, final approval; Y.K.: acquisition of data, final approval; K.N.: acquisition of data, final approval; Y.T.K.: critical analysis, final approval; H.O.: critical analysis, final approval; Y.K.: chief supervisor of the manuscript, critical revision, final approval.

Conflicts of interest disclosure

The authors declare no conflicts of interest for this article.

Research Registration Unique Identifying Number (UIN)

1. Name of the registry: Research Registry.
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3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-theregistry#home/registrationdetails/64852ad92d5ea00026a5b6f8/.

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Data availability statement

All data will be made available on a reasonable request to the corresponding author.

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