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Original Article

Hip Function Was Not Associated with the Incidence of Preoperative Deep Vein Thrombosis in Patients Undergoing Primary Total Hip Arthroplasty

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The prevalence of preoperative deep vein thrombosis (DVT) has been reported to be relatively high in patients undergoing total hip arthroplasty. We investigated the prevalence of DVT, the association between hip function and preoperative DVT, and the effect of a history of surgery in patients who underwent primary total hip arthroplasty. We retrospectively analyzed the cases of the patients who underwent primary total hip arthroplasty between April 2013 and February 2020 at our institution. We evaluated the prevalence of preoperative DVT based on the results of the patients' ultrasound screening. We performed univariate and multivariate analyses to investigate the association between the incidence of DVT and patient factors including age, sex, hip function, medical histories, and American Society of Anesthesiologists Physical Status classification. We analyzed 451 patients (494 hips). The prevalence of DVT was 14.2% (64 patients). The multivariate analysis demonstrated that increased age was an independent significant risk factor for DVT. The prevalence of preoperative DVT was relatively high among patients who underwent primary total hip arthroplasty. Preoperative DVT tended to be more prevalent in older patients. Hip function was not associated with the incidence of DVT.

Key words: total hip arthroplasty, deep vein thrombosis, hip function, ultrasound screening

Venous thromboembolism (VTE) is a disorder that includes deep vein thrombosis (DVT) and pulmonary embolism (PE). PE is the most critical complication of total hip arthroplasty (THA), causing sudden death in 0.08-2.5% of patients who undergo THA [1-3]. In this regard, the detection and prophylaxis of VTE are important. At our institute, preoperative DVT screening by ultrasound (US) is performed for all patients undergoing THA, but this practice is not employed by all institutions. A single study reported that the incidence of preoperative DVT in patients undergoing revision or primary THA was unexpectedly high, but other studies reported a corresponding DVT incidence at approx. 0.1-0.2% annually [4-7]. Almost all patients who undergo THA can move independently, and they are generally considered to be at low risk for preoperative DVT. We formulated two hypotheses regarding the high incidence of DVT in patients undergoing THA: (*i*) hip dysfunction induces a more sedentary lifestyle, which can cause DVT, and (*ii*) previous DVT due to a cause that is not related to THA (*e.g.*, prior surgery, malignancy) simply persisted. We thus speculated that a patient's hip function and/or medical history might be associated with the incidence of DVT.

We conducted the present study to (1) investigate

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the incidence of preoperative DVT in patients who underwent THA; (2) evaluate the risk factors for preoperative DVT, especially hip function; and (3) clarify the association between preoperative DVT and the post-THA clinical course.

Patients and Methods

Patients. Approval for this study was obtained from our institution's review board. Preoperative DVT was assessed retrospectively. The cases of the patients who underwent primary THA between April 2013 and February 2020 at our institution were analyzed. Patients who underwent tumor resection followed by THA were excluded. The patients' THAs were performed primarily for osteoarthritis (OA). At our institution, we also perform simultaneous bilateral THAs in patients whose general status is good, depending on the patient's preference. We retrospectively assessed the patients' histories of surgery within the prior 5 years as described below.

Deep vein thrombosis (DVT) screening. At our institution, patients undergo routine US screening for DVT within 4 weeks before their scheduled THA surgery. A medical technologist creates a report of the US results, and a cardiologist approves the report. We evaluated the instances of DVT based on these patient reports. After their THA, all of the present patients received prophylaxis for DVT and underwent a follow-up US screening within 1 week. The prophylactic treatment included the administration of a factor Xa inhibitor (edoxaban) or an anticoagulant. We evaluated the postoperative changes in DVT based on the two US screenings.

Regarding the US screening, the shape change of veins was assessed by mild compression using B-mode ultrasonography. DVT was diagnosed when the technician detected a loss of change in veins under mild compression. Visual artifacts of the DVT were also evaluated, such as brightness and fluttering by B-mode and the blood flow around the DVT shown by color Doppler imaging. A convex-type transducer for the iliac vein and a linear transducer for the other veins (*i.e.*, the femoral vein to the veins of the lower legs) were used.

In general, the patient was in the supine position when veins from the abdomen to the popliteal fossa were being examined, and he or she was in the sitting position when the veins of the lower legs were examined. The sonographic scanners and transducers used in this study are listed in Table 1. Proximal DVT was defined as DVT proximal to the popliteal fossa (*i.e.*, in the thigh), and distal DVT was defined as DVT distal to the popliteal fossa (*i.e.*, in the calf).

Clinical evaluation. Each patient's hip function was assessed using the Japanese Orthopaedic Association score (JOA Hip Score) [8]. The JOA score is based on pain (40%), range of motion (ROM) (20%), ability to walk (20%), and activities of daily living (ADLs) (20%). The score for a healthy normal hip is 100 points. The ROM of hip flexion and abduction was evaluated in five degrees. If a patient underwent bilateral THA, the worse score for ROM of the two hip joints was used.

The general status of the patients was assessed using the American Society of Anesthesiologists Physical Status (ASA-PS) classification. This classification was evaluated by an expert anesthesiologist at our institution. The patients' physical status was assessed using Charnley's categories [9]. The patients were classified into the following three categories. Category A, unilateral hip disease; category B, bilateral hip disease; and category C, multiple joint disease or other disabilities that impair walking ability.

Regarding DVTs detected preoperatively on screening, the association between the side of the planned THA and that of the DVT was assessed. The postoperative occurrence of PE was also assessed. In this study, a pulmonary embolism diagnosed with contrast-enhanced CT was defined as "PE." A PE that was only suspected based on clinical symptoms did not count as a "PE."

Table 1 Sonographic scanners used in this patient series

Sonographic scanner	Manufacturer	Linear transducer	Convex transducer
Aplio 400	Canon Medical Systems Co. (Tochigi, Japan)	7.5 MHz	3.5 MHz
Arietta 850	Hitachi (Tokyo, Japan)	6 or 10 MHz	3 MHz
Xario SSA-660A	Canon Medical Systems Co. (Tochigi, Japan)	7.5 MHz	3.5 MHz

Medical history. We checked the surgical history of the patients within the prior years including the following: (1) surgery for the face or an upper extremity (*e.g.*, surgery for a cataract or distal radius fracture), (2) surgery of the trunk (*e.g.*, surgery for lung cancer, lumbar spinal canal stenosis, or the uterus), (3) surgery for a lower extremity (*e.g.*, total knee arthroplasty, THA), (4) surgery for any malignant tumor, and (5) multiple surgeries. We analyzed the effects of this history on the incidence of DVT.

Statistical analyses. We analyzed the risk factors for preoperative DVT, and the results are presented in Table 2. A univariate analysis was performed first including the Wilcoxon test, one-factorial analysis of variance, and the chi-squared test. A multivariate analysis was then performed for the significant factors that were identified in the univariate analysis. We also investigated DVT progression. We performed a multivariate analysis for the existence of preoperative DVT and various risk factors (age, sex, body mass index [BMI], diabetes mellitus [DM], and ASA-PS classification) to identify the most relevant risk factors. The analyses were performed using the JMP Pro ver. 12 software (SAS, Cary, NC, USA). Statistical significance was set at $p < 0.05$.

Table 2 The DVT risk factors analyzed

1. Whether bilateral THA was simultaneous or not
2. Sex
3. Age
4. Diagnosis (whether the underlying diagnosis is OA or not)
5. Charnley category (A, B, or C)
6. BW
7. BMI
8. JOA score (total score, 0–100 points)
9. JOA score (pain, 0–40 points)
10. JOA score (ROM, 0–20 points)
11. JOA score (ability to walk, 0–20 points)
12. JOA score (ADL, 0–20 points)
13. ROM (flexion)
14. ROM (abduction)
15. History of operation for the face or upper extremity (Op FU)
16. History of operation for the trunk (Op T)
17. History of operation for the lower extremity (Op L)
18. History of operation regarding malignant disease (Op MD)
19. History of multiple operations (MOp)
20. History of DM
21. ASA-PS classification

Nos. 15–19 (history of operation) are abbreviated to the word in brackets.
THA, total hip arthroplasty; OA, osteoarthritis; BW, body weight; BMI, body mass index; JOA, Japanese Orthopaedic Association; ROM, range of motion; DM, diabetes mellitus; ASA-PS. American Society of Anesthesiologists Physical Status.

Results

We analyzed the cases of 451 patients (494 hips): 408 hips underwent unilateral THA and 86 hips in bilateral THA group (Fig. 1). The patients' demographic data are shown in Table 3. The underlying diagnoses were OA (n = 405 patients), osteonecrosis of the femoral head (ONFH) (20 patients), hip fracture (13 hips), post-fracture (five patients), rheumatoid arthritis (RA) (four patients), and other diagnoses (four patients). The other diagnoses included systemic lupus erythematosus in one patient, traumatic OA in one patient, and postoperative arthropathy in two patients.

Preoperative DVT was observed in 64 patients (14.2%). Of these, proximal DVT was recognized in four (0.89%): one patient had DVT in the external iliac

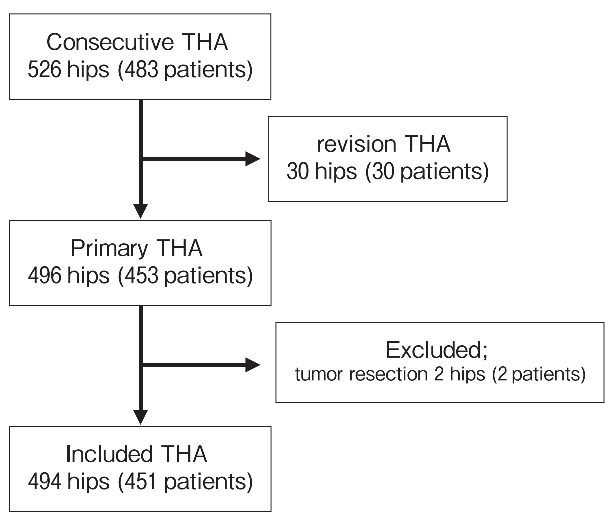

Fig. 1 The flow chart of the included cases.

vein, two had DVT in the popliteal vein, and one had a superficial femoral vein involvement. Three of the four patients were diagnosed with OA, and the other patient was diagnosed with ONFH. They were treated with anticoagulant only and did not undergo the placement of an inferior vena cava filter. Regarding the distal DVTs, the soleus vein was affected in all 60 of the distal DVT patients (13.3%); in addition, the posterior tibial vein and peroneal vein showed DVTs in two and one patients, respectively. Multiple distal DVTs were observed in three patients. No additional treatment was performed for the patients with preoperative distal DVT. In addition, the side of the DVT was not associated with the side of the planned THA (Table 4). None of the patients in this study developed PE postoperatively.

Regarding postoperative changes in DVT, progression was observed in 17 patients with preoperative DVT and 33 patients without preoperative DVT. Among the 17 patients with preoperative DVT, five showed new-onset DVT in the contralateral leg, and the other 12 patients showed enlargement of the pre-existing DVT. Progression was significantly more frequent in the patients with preoperative DVT compared to those without preoperative DVT ($p < 0.001$).

We analyzed the risk factors among the preoperative variables. The results are presented in Table 5. Age, Charnley's category, JOA score (ADLs), history of trunk surgery, and ASA-PS classification were significant factors impacting the incidence of DVT. In the multiple regression analysis, increased age was the only significant factor. Regarding Charnley's categories, category C was a significant risk factor compared to category B but not category A (Table 6). Our analysis of the risk factors for DVT progression during the postoperative period revealed that DVT progression was independently associated with age as well as the existence of preoperative DVT (Table 7).

Table 3 Demographic data of the patients

	Total 451 patients
Bilateral THA	B 43 H 408
Sex (male %)	63 (14.0%)
Age	68.7 ± 9.4 y.o.
Laterality	B 43 R 221 L 187
Charnley category	A 328 B 79 C 44
BW	56.0 ± 10.7 kg
Height	153.7 ± 8.0 cm
BMI	23.7 ± 3.8
JOA score (total)	37.6 ± 12.5
JOA score (pain)	10.7 ± 6.3
JOA score (ROM)	12.3 ± 3.6
JOA score (ability to walk)	7.8 ± 3.8
JOA score (ADL)	6.9 ± 3.5
ROM (flexion)	84.5 ± 18.0
ROM (abduction)	18.9 ± 8.2
Op FU	(+) 49 (−) 402
Op T	(+) 63 (−) 388
Op L	(+) 82 (−) 369
Op MD	(+) 20 (−) 431
MOp	(+) 39 (−) 412
History of DM	(+) 47 (−) 404
ASA-PS	1.95 ± 0.45

Values are means ± standard deviations (SDs).
Laterality: B, bilateral; R, right; L, left.
THA, total hip arthroplasty; JOA, Japanese Orthopaedic Association; ROM, range of motion; ADL, activities of daily living; Op FU operation for the face or upper extremity; Op T, operation for the trunk; Op L, operation for the lower extremity; Op MD, operation regarding malignant disease; Mop, multiple operations; DM, diabetes mellitus; ASA-PS, American Society of Anesthesiologists Physical Status; SD, standard deviation

Table 4 The association between the laterality of DVT and the planned hip operation

	THA side right	THA side left	THA side bilateral
Right DVT +	18	19	1
Right DVT −	203	168	42

Right: $p = 0.1692$

	THA side right	THA side left	THA side bilateral
Left DVT +	19	20	2
Left DVT −	202	167	41

Left: $p = 0.3966$
The chi-squared test was performed.
THA, total hip arthroplasty; DVT, deep vein thrombosis

Table 5 Univariate analysis of the risk factors for preoperative DVT

	DVT (+) N=64	DVT (−) N=387	*P*-value
Bilateral THA†	B 3 H 61	B 40 H 347	0.122
Sex (male %)†	5 (7.81%)	58 (15.0%)	0.102
Age‡	72.9 ± 9.0	68.0 ± 9.3	<0.0001*
Diagnosis (OA %)†	55 (85.9%)	350 (90.4%)	0.290
Charnley category†	A 47 B 4 C 13	A 281 B 75 C 31	0.001*
BW‡	55.2 ± 1.3	56.2 ± 0.5	0.522
BMI‡	23.5 ± 0.5	23.7 ± 0.2	0.790
JOA score (total)‡	35.9 ± 13.4	37.9 ± 12.3	0.238
JOA score (pain)††	10.5 ± 6.3	10.7 ± 6.3	0.883
JOA score (ROM)‡	11.9 ± 2.9	12.3 ± 3.6	0.401
JOA score (ability to walk)††	6.9 ± 4.1	7.9 ± 3.7	0.055
JOA score (ADL)††	6.0 ± 3.3	7.0 ± 3.5	0.029*
ROM (flexion)‡	85.6 ± 15.6	84.3 ± 18.4	0.575
ROM (abduction)‡	18.3 ± 8.2	19.1 ± 8.2	0.483
Op FU	(+) 7 (−) 57	(+) 42 (−) 345	0.984
Op T	(+) 14 (−) 50	(+) 49 (−) 338	0.049*
Op L	(+) 17 (−) 47	(+) 65 (−) 322	0.061
Op MD	(+) 2 (−) 62	(+) 75 (−) 312	0.583
MOp	(+) 8 (−) 56	(+) 31 (−) 356	0.237
History of DM†	(+) 3 (−) 61	(+) 44 (−) 343	0.077
ASA-PS††	2.11 ± 0.31	1.93 ± 0.47	0.0024*

† chi-squared test †† Mann-Whitney *U* test ‡ Student's *t*-test * Statistical significance was recognized.
DVT, deep vein thrombosis; THA, total hip arthroplasty; OA, osteoarthritis; BW, body weight; BMI, body mass index; JOA, Japanese Orthopaedic Association; ROM, range of motion; ADL, activities of daily living; Op FU, operation for the face or upper extremity; Op T, operation for the trunk; Op L, operation for the lower extremity; Op MD, operation regarding malignant disease; MOp, multiple operations; DM, diabetes mellitus; ASA-PS, American Society of Anesthesiologists Physical Status

Table 6 Multivariate analysis of the risk factors for preoperative DVT

Age	0.96/year (0.93–0.99)	0.018*
ADL	1.02/point (0.93–1.11)	0.686
Op T	1.48 (0.71–2.91)	0.285
ASA-PS	0.52 (0.264–1.01)	0.056
Charnley's category	A vs C 1.73 (0.78–3.65) B vs C 4.50 (1.39–17.53) A vs B 0.38 (0.11–1.00)	0.171 0.011* 0.052

* Statistical significance was recognized.
ADL, activities of daily living; Op T, operation for the trunk; ASA-PS, American Society of Anesthesiologists Physical Status

Table 7 Multivariate analysis of the risk factors for DVT progression

	P-value
Age	0.001*
DVT†	0.002*
Sex	0.006*
History of DM	0.181
ASA-PS	0.448
BMI	0.620

* Statistical significance was recognized.
† DVT = the existence of preoperative DVT

Discussion

We analyzed the cases of 451 patients who underwent a primary THA, of whom 64 had preoperative DVT. The patients with preoperative DVT showed greater development/progression of DVT postoperatively. A multivariate analysis showed that older age was also a significant risk factor for DVT progression, and Charnley's category was somewhat relevant. Hip function was not strongly associated with the incidence of DVT.

Preoperative DVT was observed in 14.2% of the present patients (64/451). Wakabayashi *et al.* reported a 12.3% prevalence of preoperative DVT in patients undergoing primary THA or revision [7]. However, another report showed an only 3.9% prevalence of asymptomatic preoperative DVT in primary THA [10]. The differences in DVT prevalence might be attributable to (*i*) the difference in the mean age of the patients in each study (a significant number of older patients were included in our study) and (*ii*) whether revision THA was included. Several studies have reported the prevalence of DVT before surgeries other than THA; the rates of preoperative DVT in patients undergoing cancer-related surgery ranged from 7.8% to 13.9% [11-13]. Our present results demonstrated a higher DVT prevalence, although all of the patients were cancer-free. This suggests that hip disease, like cancer, may increase the prevalence of DVT regardless of hip function. The underlying mechanism is unknown, but we speculate that inflammatory processes around the hip may exacerbate clot formation in the lower leg.

The prevalence of PE in patients with proximal DVT is estimated to be 40-50% [14], but only four of our patients had proximal DVT. Most of the cases of DVT observed in this study were thromboses limited to deep veins in the lower leg, sometimes called "isolated distal DVT (IDDVT)." The optimal treatment for distal DVT is controversial [15, 16]. The American College of Clinical Pharmacy guidelines suggests anticoagulation or serial imaging for IDDVT [17]. Palareti reported that while proximal extension was rare, the presence of IDDVT was associated with DVT-related complications, and IDDVT was clinically significant [18]. By contrast, preoperative IDDVT in the present study did not alter any treatment or extend to the proximal veins, we therefore do not recommend routine preoperative US screening for DVT, despite the progression of 27% of preoperative DVT after THA .

Medical students everywhere still learn about Virchow's triad: the observation by Rudolf Virchow in 1856 that blood hypercoagulability, hemodynamic change of blood flow, and endothelial injury are the three factors required for thrombus formation [19]. Based on this principle, we hypothesized that increased immobility due to hip disease would contribute to DVT. In our patient series, the "ability to walk" score on the JOA's scale was not associated with the incidence of DVT in the univariate analysis, possibly due to the small number of patients in that category. However, the "ADLs affected" score on the JOA scale was associated with DVT incidence. These results suggest that DVT might occur when hip dysfunction induces more subtle disabilities than not being able to walk, which nonetheless restrict daily activity. This hypothesis may be supported by our finding that the Charnley category C, which is associated with multiple joint disease, was a significant risk factor for preoperative DVT.

Regarding risk factors, our present findings are notable. For example, type 2 diabetes mellitus (DM) has been reported to be a risk factor for DVT [20, 21]. In patients undergoing total knee arthroplasty, the presence of DM increased the incidence of DVT during the period ≤ 14 postoperative days [22, 23]. Other risk factors for DVT have been reported, including age, obesity, cancer, prolonged immobility, stroke, major surgery, trauma, congestive heart failure, pregnancy, acute infection, dehydration, RA, dyslipidemia, and genetic factors [4, 24-26]. However, in the present analyses, DM, BMI, and history of surgery for malignant disease were not associated with the risk of DVT. This discrepancy might be attributed to the fact that the DVTs observed in our study were mainly IDDVTs. Galanaud *et al.* showed that IDDVT occurred more frequently in patients with transient risk factors, and proximal DVT was observed in patients with chronic risk factors [27]. We may thus have had fewer cases with chronic factors including DM, obesity (BMI), and a poor ASA-PS classification.

Regarding malignant disease, a history of surgery for malignant disease was not associated with the risk for DVT in our series simply because none of the patients undergoing THA had active cancer. Wakabayashi *et al.* showed that increased age, RA, and history of major surgery were risk factors for preoperative DVT in patients undergoing a THA [7]. In the present study, history of surgery was not identified as a significant risk factor for DVT. We did not analyze surgical parameters in great detail; however, specific types of prior surgery did have a weak association with the incidence of DVT.

Regarding RA, patients with multi-joint disease or other diseases that impair walking ability may have RA-like status, classified as Charnley's category C. Our observation that the patients in category C showed a higher incidence of DVT compared to those in category B is similar to a finding reported in Wakabayashi's study. We did not detect chronic risk factors such as increased age, Charnley's category C, and RA as risk factors for DVT. Rather, our results seemed to suggest that patients with these factors may have a higher incidence of other events, such as a reduction in ADLs, that can in turn trigger DVT.

This study has some limitations. The reliability of ultrasound screening for DVT (especially for distal DVT) is not established. Ultrasound was reported to have higher sensitivity for proximal DVT than for distal DVT [28, 29]. In addition, our patients' underlying diagnoses could not be assessed. In this series, 89.8% of the patients underwent total hip arthroplasty for OA. We could not analyze the underlying diagnoses in detail because the number of patients diagnosed with RA and other diseases were few compared to those diagnosed with OA. Lastly, we did not evaluate the DVT pathologies in detail. Some of the DVTs seemed organized and old. Confirming whether a DVT is new is considered subjective. Regardless, this point could not be analyzed.

The influence of recent surgery may need to have a more restrictive definition than our category, *i.e.*, "within 5 years." Moreover, we employed the JOA score for assessing the patients' hip function. Except for the pain component, the JOA score is an objective score. Patient-reported outcome measures may be better for assessing hip function and its impact on activity.

In conclusion, the incidence of DVT in the patients who underwent THA in our series was high. Distal DVT and proximal DVT were detected in 13.3% and 0.89% of the patients, respectively. The results of ultrasound screening did not alter treatment. Increased age was the only significant risk factor for preoperative DVT. Hip function was not a significant factor according to the results of a multivariate analysis. Age was associated with the postoperative progression of DVT as well as its presence preoperatively.

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