Venous Hemodynamic Alterations in Lower Limbs Undergoing Total Joint Arthroplasty

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Abstract

Using duplex ultrasonography, we measured preoperative and postoperative venous flow volume in 32 operated lower limbs without deep vein thrombosis (DVT) after total hip arthroplasty (THA, n = 17) and total knee arthroplasty (TKA, n = 15). We also calculated percentage decrease in mean venous flow volume (MVFV) from before surgery to after surgery. Patients with a history of one of several venous diseases, congestive heart failure, or morbid obesity were excluded.

In both groups (THA, TKA), MVFV 3 days after surgery and MVFV 1 week after surgery were significantly lower than preoperative MVFV, but MVFV at 2 or more weeks after surgery did not differ significantly from preoperative MVFV (result 1). Incidentally, the decrease in MVFV in the lower limbs was significantly larger 3 days after TKA than 3 days after THA (result 2).

As venous stasis has a central role in thrombus formation, result 1 suggests that the risk for DVT initiation is low at 2 or more weeks after THA and TKA in patients with normal preoperative venous physiologic functions. Result 2 is probably correlated with the evidence that DVT incidence is higher after TKA than after THA.

Deep vein thrombosis (DVT) is a serious complication of total joint arthroplasty (TJA), because it can cause fatal pulmonary embolism.[1,2] The incidence of DVT in the absence of thrombosis prophylaxis has ranged from 20% to 40% after total hip arthroplasty (THA) and from 50% to 80% after total knee arthroplasty (TKA).[2-5]

Venous stasis, endothelial cell dysfunction, and activated clotting factors are the major factors for DVT initiation.[6] Thomas[6] wrote that endothelial cell dysfunction and activated clotting factors are weak initiators of a venous thrombus when venous stasis is absent and that venous stasis has a central role in initiation of a venous thrombus. We therefore consider that assessment of duration of venous stasis in operated lower limbs without DVT after TJA is a key to knowing when the risk for initiation of postoperative DVT decreases.

In the study reported here, we evaluated duration of postoperative venous stasis in operated lower limbs without DVT after THA and TKA to ascertain when the risk for initiation of postoperative DVT decreases. Using duplex ultrasonography, a popular modality for evaluating venous flow,[7-10] we investigated preoperative and postoperative venous hemodynamics in operated lower limbs without DVT after THA and TKA.

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Materials and Methods

We recruited patients who had undergone primary and unilateral THA or TKA for osteoarthritis at our department between April 1999 and March 2004. Patients with a history of DVT, pulmonary embolism, varicose veins, phlebitis, venous insufficiency, congestive heart failure, or morbid obesity (body mass index, ≥30.0) were excluded. Other patients were excluded when DVT was detected or suspected approximately 4 weeks after surgery using ultrasonography or ascending venography.[11-14] Consequently, 17 operated lower limbs of 17 THA patients and 15 operated lower limbs of 15 TKA patients were completely studied. Clinical details of the 32 patients (age, sex, height, weight, amount of intraoperative and postoperative blood loss) are summarized in Table I. All THAs and TKAs were performed with the patient under spinal and epidural anesthesia. All TKAs were performed with use of a thigh tourniquet. After all THAs and TKAs, the suction drain was removed on postoperative day 2, and ambulation was initiated between postoperative days 5 and 10. After TKA, continuous passive motion was started on postoperative day 2. After all THAs and TKAs, a foot-pump system was used until postoperative day 3. However, none of the patients included in this study received chemical prophylaxis against thrombosis. All patients were informed of the purpose, procedure, and known risks of this study. Informed consent was obtained from all patients.

Ultrasound was used to measure venous flow volume in the operated lower limbs 1 day before surgery and 3 days and 1, 2, 3, and 4 weeks after surgery. To eliminate potential interobserver variation, we had a single experienced technician perform all measurements. For all measurements, each patient lay on a bed in a supine position with

Table I. Patients' Clinical Details, Means (SDs)

Detail	Group THA (n = 17)	TKA (n = 15)	Total (n = 32)	P^b
Age, y	63.9 (8.3)	68.1 (6.4)	65.9 (7.6)	.130
Sex, no. male/female	2/15	2/13	4/28	—
Height, cm	155.3 (8.0)	152.4 (6.8)	153.9 (7.5)	.281
Weight, kg	51.7 (11.0)	57.1 (5.6)	54.2 (9.2)	.091
Total[a] blood loss, mL	791 (167)	714 (91)	755 (140)	.111

Abbreviations: SD, standard deviation; THA, total hip arthroplasty; TKA, total knee arthroplasty.
[a]Intraoperative plus postoperative. [b]THA–TKA comparison made with Student or Welch *t* test.

quiet respiration. Venous flow volume was measured in the common femoral vein approximately 2 cm above the junction of the greater saphenous and femoral veins using duplex ultrasonography with computed sonography and a 7.5-MHz linear-array transducer (SSD-2000; Aloka Inc, Tokyo, Japan). At first, we obtained a full image of the common femoral vein by color flow mode (Figure 1A). We measured the vein diameter and calculated the cross-sectional area of the vein. We adjusted the angle between the direction of the ultrasound beam and that of the lumen of the vein to 60° using steered beam function. After putting a screen cursor at the center of the lumen, we recorded and autotraced real-time signals of venous flow velocities by Doppler mode for 1 minute (Figure 1B). We measured mean venous flow velocity during that minute. Venous flow volume (mL/min) was defined as cross-sectional area of vein (cm^2) × mean venous flow velocity (cm/s) × 60 (s). In each duplex ultrasound examination, venous flow volume was measured 3 times, and the between-measurements interval was 3 minutes. We calculated mean venous flow volume (MVFV) from the 3 measured values. We also calculated percentage decrease in MVFV from 1 day before surgery to after surgery: percentage decrease in MVFV (%) = (preoperative MVFV – postoperative MVFV) × 100 / preoperative MVFV.

In both groups (THA, TKA), we used repeated-measures analysis of variance and then Scheffé *F* test to compare each postoperative MVFV with MVFV 1 day before surgery. We used the Student or Welch *t* test to compare THA and TKA data. Two-tailed *P* was reported. Level of significance was set at *P*<.05.

Results

The THA and TKA groups did not differ significantly in their clinical characteristics (age, *P* = .130; height, *P* = .281; weight, *P* = .091; amount of intraoperative and postoperative blood loss, *P* = .111) and were well matched in number of male/female patients (THA, 2/15; TKA, 2/13) (Table I). Neither symptomatic DVT nor pulmonary embolism was observed in any patient until the most recent follow-up.

MVFV measurements are listed in Table II and shown in Figure 2. In the THA group, MVFV 3 days after surgery and MVFV 1 week after surgery were significantly lower than MVFV 1 day before surgery (*P*s<.001), but MVFV at 2, 3, and 4 weeks after surgery did not differ significantly from MVFV 1 day before surgery (*P*s = .164, .877, and .992, respectively) (Figure 2). Similarly, in the TKA group, MVFV 3 days after surgery and MVFV 1 week after surgery were significantly lower than MVFV 1 day before surgery (*P*s<.001), but MVFV at 2, 3, and 4 weeks after surgery did not differ significantly from MVFV 1 day before surgery (*P*s = .120, .827, and .996, respectively) (Figure 2). In addition, the THA and TKA groups did not differ significantly at any MVFV measurement time: 1 day before surgery (*P* = .700) and 3 days and 1, 2, 3, and 4 weeks after surgery (*P*s = .278, .683, .994, .857, and .728, respectively) (Table II).

Percentage decreases in MVFV for the THA and TKA groups are listed in Table III. Percentage decrease in MVFV was significantly larger for the TKA group than for the THA group 3 days after surgery (*P* = .032) but did not differ significantly 1, 2, 3, and 4 weeks after surgery (*P*s = .168, .350, .268, and .571, respectively) (Table III).

Discussion

Our results demonstrate that venous stasis in operated lower limbs without DVT persists until at least 1 week after

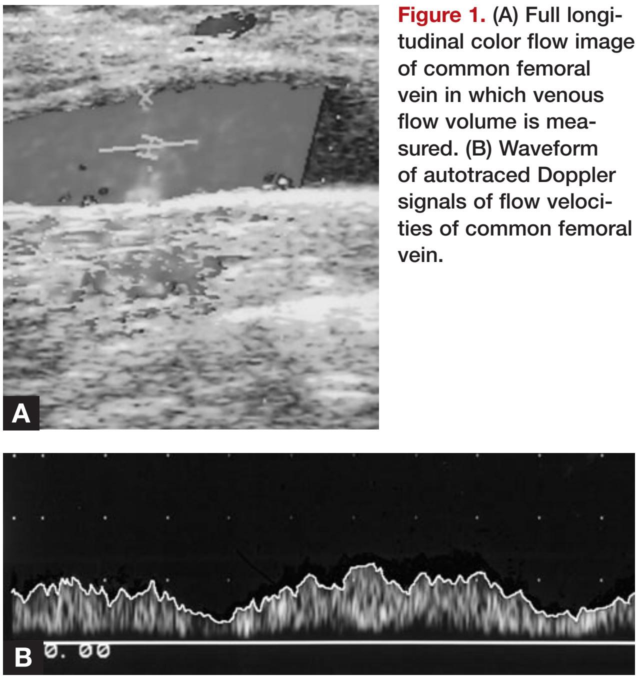

Figure 1. (A) Full longitudinal color flow image of common femoral vein in which venous flow volume is measured. (B) Waveform of autotraced Doppler signals of flow velocities of common femoral vein.

Table II. Mean Venous Flow Volume (mL/min) in Operated Lower Limbs, Means (SDs)

Time Before/ After Surgery	Group		
	THA (n = 17)	TKA (n = 15)	P^a
1 day before	328 (27)	332 (26)	.700
3 days after	288 (25)	277 (30)	.278
1 week after	303 (22)	299 (25)	.683
2 weeks after	320 (26)	320 (30)	.994
3 weeks after	324 (26)	326 (27)	.857
4 weeks after	326 (26)	329 (27)	.728

Abbreviations: SD, standard deviation; THA, total hip arthroplasty; TKA, total knee arthroplasty.
[a]THA–TKA comparison made with Student *t* test.

Table III. Percentage Decrease[a] in Mean Venous Flow Volume (mL/min) in Operated Lower Limbs, Means (95% CIs)

Time After Surgery	Group		
	THA (n = 17)	TKA (n = 15)	P^b
3 days	12.2 (9.8-14.6)	16.5 (13.1-19.9)	.032
1 week	7.6 (5.8-9.4)	9.7 (7.0-12.4)	.168
2 weeks	2.3 (1.4-3.1)	3.4 (0.8-6.0)	.350
3 weeks	1.1 (0.6-1.5)	1.7 (0.6-2.7)	.268
4 weeks	0.6 (0.2-0.9)	0.7 (0.3-1.1)	.571

Abbreviations: CI, confidence interval; THA, total hip arthroplasty; TKA, total knee arthroplasty.
[a]From 1 day before surgery to time after surgery. [b]THA–TKA comparison made with Student or Welch *t* test.

THA and after TKA but is absent at 2 or more weeks after both operations. Several local and systemic factors, which are altered by surgical invasion, cause postoperative venous stasis in lower limbs that undergo TJA. The causes of postoperative venous stasis are too complicated to describe entirely. Moreover, it is unknown why the venous hemodynamics in operated lower limbs without DVT recover to preoperative levels approximately 2 weeks after THA and after TKA.

In our study, preoperative venous physiologic functions were normal probably because the patients did not have a history of DVT, pulmonary embolism, varicose veins, phlebitis, venous insufficiency, congestive heart failure, or morbid obesity. However, we suggest that, in patients with a history of any of these disorders, even when DVT is absent after TJA, venous stasis might persist for 2 or more weeks after surgery because these patients' venous physiologic functions might have failed before surgery.

Thomas[6] indicated that venous stasis has a central role in initiation of a venous thrombus. Our study results suggest that risk for DVT initiation is low at 2 or more weeks after THA and after TKA in patients with normal preoperative venous physiologic functions. Although we included only Japanese patients in this study, we believe that Western surgeons can accept its results, as Fujita and colleagues[5] found Japanese and Western[4] TJA populations to be comparable in incidence, location, and size of venous thrombi.

Low-molecular-weight heparin (LMWH), warfarin, and fondaparinux are popular and effective chemical agents for prophylaxis against initiation of DVT after TJA.[1,15] There is general agreement that surgeons need to perform chemical prophylaxis against DVT initiation for at least 10 days after TJA.[1,16-18] Given our results, we consider this a reasonable view. Incidentally, some investigators have recommended performing chemical prophylaxis against DVT initiation for more than 4 weeks after TJA.[1,19-21] However, LMWH, warfarin, and fondaparinux are associated with bleeding complications.[22,23] Aspirin, though less effective as an antithrombotic agent,[1,24] is safer with regard to causing bleeding complications.[22,23] Our results suggest that, when chemical prophylaxis against DVT initiation is performed for more than 2 weeks after TJA, in patients with normal preoperative venous physiologic functions, surgeons should administer aspirin instead of LMWH, warfarin, or fondaparinux 2 or more weeks after THA and after TKA, taking bleeding complications into consideration.

In our study, percentage decrease in MVFV 3 days after surgery was significantly larger for the TKA group than for the THA group. This result suggests that the intraoperative influence of TKA on venous hemodynamics in operated lower limbs is probably larger than the intraoperative influence of THA. This result is also probably correlated with the evidence that DVT incidence is higher after TKA than after THA, in both Western and Japanese populations.[3-5] Incidentally, the THA and TKA groups in our study did not differ significantly in percentage decrease in MVFV 1 or more weeks after surgery; the implication is that these groups might not differ in risk for DVT initiation 1 or more weeks after surgery. However, it is unknown why the venous hemodynamics in operated lower limbs without DVT after THA and after TKA are similar at 1 or more weeks after surgery.

In Japan and North America, patients are encouraged by medical staff to perform active and passive exercises of the hip, knee, ankle, and foot as soon as possible after TJA. However, Japanese patients start ambulation later after

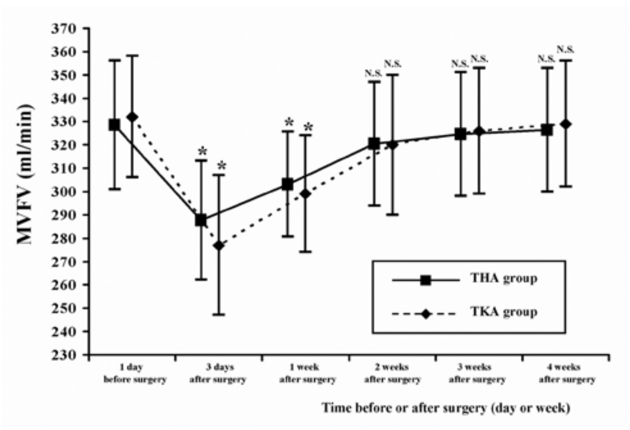

Figure 2. Postoperative alterations in mean venous flow volume (MVFV) in operated lower limbs in total hip arthroplasty (THA) and total knee arthroplasty (TKA) groups. Each MVFV after surgery is compared with MVFV 1 day before surgery using repeated-measures analysis of variance and then Scheffé *F* test. *Significantly lower than value 1 day before surgery ($P<.001$); NS, not significantly different from value 1 day before surgery.

surgery than North American patients do. In our study, ambulation was started between postoperative days 5 and 10; in another Japanese study on DVT,[5] it was started between postoperative days 7 and 14. In Japan, unlike in North America, patients who undergo TJA are hospitalized for about 4 weeks, and therefore it is not necessary to rush postoperative initiation of ambulation. In Japan, it is common practice to start ambulation approximately 1 week after either THA or TKA, as severe postoperative pain has decreased to some extent by then. We suggest that a 1-week delay in postoperative initiation of gait might not significantly influence postoperative venous hemodynamics because the incidence, location, and size of venous thrombi are comparable for Japanese and Western TJA populations.[5]

Conclusions

Our results demonstrate that venous stasis in operated lower limbs without DVT is absent at 2 or more weeks after THA and after TKA in patients with normal preoperative venous physiologic functions. We therefore suggest that the risk for DVT initiation is low at 2 or more weeks after THA and after TKA in patients with normal preoperative venous physiologic functions. Incidentally, our results also demonstrate that the degree of venous stasis in operated lower limbs without DVT is higher 3 days after TKA than 3 days after THA. This result is probably correlated with the evidence that DVT incidence is higher after TKA than after THA. However, because our study had a small number of subjects, we need to check the reliability of its results. To do that, we need to investigate preoperative and postoperative venous hemodynamics in operated lower limbs without DVT after THA and TKA in larger populations.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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