Not Using a Tourniquet May Reduce the Incidence of Asymptomatic Deep Venous Thrombosis After ACL Reconstruction

An Observational Study

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Background: Deep venous thrombosis (DVT) and pulmonary embolism are serious potential complications after anterior cruciate ligament reconstruction (ACLR). Little is known about the influence of tourniquet use on the incidence of DVT after ACLR.

Purpose: To compare the incidence of DVT after ACLR with and without the use of a tourniquet.

Study Design: Cohort study; Level of evidence, 3.

Methods: Between November 2018 and May 2020, a total of 60 consecutive ACLRs in 60 patients, including 7 revision surgeries, were performed without tourniquet use at our hospital and were enrolled in this study (T– group). In addition, 55 consecutive ACLRs in 55 patients, including 10 revision surgeries, were performed with tourniquet use between April 2017 and September 2018 and were enrolled as the control group (T+ group). DVT was diagnosed using ultrasonography of both legs performed preoperatively and at postoperative week 1. The incidence of postoperative DVT was compared between the T– and T+ groups. Logistic regression analysis was performed to evaluate the effect of older age ($\geq$40 vs $<$40 years) and tourniquet use on the occurrence of DVT.

Results: No DVTs were detected preoperatively. The incidence of postoperative DVT was significantly lower in the T– group compared with the T+ group (1 patient [1.7%] vs 9 patients [16.4%]; $P = .005$). All patients with DVT were asymptomatic. Although the mean operative time was not significantly different (80.8 minutes in the T+ group vs 78.5 minutes in the T– group; $P = .461$), the mean blood loss from the drain was significantly lower in the T– group than in the T+ group (149.9 vs 201.9 mL; $P < .001$). Age $\geq$40 years and tourniquet use were significantly related to the occurrence of DVT (odds ratio, 8.3 [95% CI, 1.9-36.8]; $P = .005$; and odds ratio, 8.8 [95% CI, 1.0-75.3]; $P = .047$, respectively).

Conclusion: ACLRs performed without tourniquet resulted in a significantly lower incidence of DVT after ACLR and significantly less bleeding from drains. If adequate visibility of the surgical field is obtained, ACLR without tourniquet use may reduce the incidence of DVT.

Keywords: anterior cruciate ligament; deep venous thrombosis; tourniquet

Venous thromboembolism (VTE), which includes deep venous thrombosis (DVT) and pulmonary embolism (PE), is a serious potential complication after anterior cruciate ligament (ACL) reconstruction (ACLR). DVT has the potential to develop into life-threatening PE. Although the incidence of DVT after ACLR has been reported to be as low as 0.30% to 0.50% in large database studies,[1,6,9,12] it has been reported to range between 6.6% and 41.2% when examined by contract venography, ultrasonography, and magnetic resonance venography.[4,15,18,20,22,24] Thus, large databases may underestimate this incidence. The incidence of PE after ACLR has been reported to range from 0.05% to 0.21% in large database studies,[1,6,9,12] but there are few reports of PE examined by contrast-enhanced computed tomography (CECT). When PE is actually examined by CECT, the incidence is likely to be quite high, as is the case with DVT.

In a previous study,[18] VTEs were investigated using ultrasonography and CECT after ACLR with the use of a tourniquet. In that study, patients diagnosed with DVT

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underwent CECT to detect PE. The authors reported that 9 of 55 patients (16.4%) had DVT, and 4 of those (at least 7.3%) had PE.[18] Although all the cases were asymptomatic, the incidence of PE was revealed to be unexpectedly high. To the best of the authors' knowledge, routine screening for DVT has not been shown to reduce the rate of fatal PE. However, asymptomatic DVT has been reported to be associated with increased risk of short-term all-cause mortality in patients hospitalized with an acute medical illness,[10] and with postthrombotic syndrome.[23] Moreover, there have been reports of cases with fatal VTE after ACLR,[2,11,17] suggesting that the focus should be placed on the prevention of DVT.

Older age,[1,6,9,12,18,20,22,24] additional ligament reconstructions,[4,22] high tibial osteotomy,[1] and prolonged tourniquet use[4] have been reported as risk factors for DVT after ACLR. Although tourniquet use is important for securing arthroscopic visibility, it causes venous stasis of the lower extremity, which may be a risk factor for DVT. There is a potential to reduce the incidence of DVT by completely avoiding the use of a tourniquet. However, this possible reduction has not been determined clearly.

The purpose of this study was to compare the incidence of DVT after ACLR with, versus without, the use of a tourniquet. It was hypothesized that ACLR without a tourniquet leads to less incidences of DVT than ACLR performed with a tourniquet.

METHODS

Patients

The protocol for this cohort study was approved by our institutional review board, and written informed consent was obtained from all patients. Between November 1, 2018 and May 31, 2020, a total of 60 consecutive ACLRs in 60 patients, including 7 revision surgeries, were performed without the use of tourniquet at our hospital (T– group). The control group consisted of 55 historical ACLRs in 55 patients, including 10 revision surgeries, that were performed with tourniquet use at our hospital between April 1, 2017 and September 30, 2018 (T+ group). Since April 2017, perioperative DVT prophylaxis and examination has been performed routinely with the same protocol in our hospital. The exclusion criteria were the same for both groups and were as follows: (1) patients with a history of VTE; (2) patients with DVT diagnosed by preoperative ultrasound; and (3) patients who required additional ligament surgery or high tibial osteotomy. Although 1 patient who had a history of PE was excluded in the T+ group, there were no patients who required additional surgery in either group. No patients were lost to follow-up or had missing data, because all study patients had requested to be hospitalized for at least 1 week after surgery (the Japanese universal health insurance system allows more than 7 days of hospitalization for patients undergoing ACLR).

Surgical Procedures and Postoperative Care

All ACLRs were performed by an experienced surgeon (M.N.), with the patient under general anesthesia with femoral and sciatic nerve blocks. In both groups, the same ACLR procedures were performed except for the use of tourniquet. In the T+ group, the tourniquet was used only during arthroscopic procedures. At first, the graft was harvested and prepared without the use of a tourniquet. The arthroscopic procedure was then started using a tourniquet. The tourniquet pressure was set to range from 250 mm Hg, to 280 mm Hg and the affected limb was exsanguinated before tourniquet pressurization. In the T– group, the tourniquet was not applied, and an irrigation pump (Dyonics 25; Smith & Nephew) was used, and the pressure was set at 60 mm Hg but was adjusted according to the bleeding conditions with a maximum of 80 mm Hg. In both groups, a radio frequency device (Quantum 2; Smith & Nephew) was also used intraoperatively to control bleeding.

ACLs were reconstructed using single-bundle hamstring autografts. For graft preparation, a commercially available polyester tape (Leeds-Keio artificial ligament; Neoligament) was connected at the distal end of the graft, and an Endobutton CL BTB or Ultra Button (Smith & Nephew) was attached at the proximal end of the graft. The graft was introduced through each tibial tunnel and the femoral tunnel made with the transportal technique. The diameter of the bone tunnel was matched to the diameter of the hamstring autografts. The diameter of the autograft was between 8 and 10 mm. Fixation of the graft was performed with an Endobutton or Ultra Button on the femoral side and 2 staples on the tibial side. For revision ACLR, the hamstring autograft was harvested from the contralateral side, and the procedure was performed in the same manner as primary reconstruction. If meniscus tears existed and were repairable, they were repaired with the all-inside

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technique using FastFix-360 (Smith & Nephew) or the outside-in technique. Middle-to-posterior meniscus injuries were repaired with the all-inside technique, and anterior meniscal injuries were repaired with the outside-in technique. A closed-suction drain was installed and left in the knee for 24 hours.

Postoperatively, the knee was immobilized with a brace for 1 day for patients without meniscal repair and for 5 days for patients with meniscal repair. After immobilization, range-of-motion exercises and muscle strengthening were started. On postoperative day 7, full weightbearing with a hinged knee brace was permitted. For DVT prophylaxis, intermittent pneumatic compression of the foot was applied to the contralateral limb during ACLR. Although no patients received pharmacological prophylaxis, intermittent pneumatic compressions for both feet were used for 1 day, and compression stockings that covered entire bilateral lower limbs were used for 7 days postoperatively.

Diagnosis and Management of DVT

Ultrasound examination (TUS-X100; Canon Medical Systems) of both legs was performed preoperatively and on postoperative day 6 or 7 (depending on availability of the device) to detect DVT. In this study, DVT was defined as a venous thrombus located inside the deep fascia. DVT was diagnosed using both a compression technique and color Doppler evaluation. All examinations were performed and evaluated by a single experienced vascular surgeon (N.O.). The diagnosed DVTs were treated with oral anticoagulation therapy with apixaban (5 mg twice daily), or edoxaban (60 mg once daily), and continued until the DVT resolved on ultrasound.

Outcomes

The primary outcome of this study was the incidence of DVT. Operative time and blood loss from the drain, which might be affected by the use of tourniquet, were defined as secondary outcomes in this study.

Data Collection

We recorded preoperative clinical and surgical data including age, sex, body mass index (BMI), D-dimer value, current smoking status, Lysholm score, interval from injury to ACLR (<3 vs ≥3 months), primary or revision ACLR, and presence or absence of meniscal repair. Postoperative data, including D-dimer value on postoperative days 1 and 7, were also recorded.

Statistical Analysis

In addition to the primary and secondary outcomes, clinical factors were compared between the T– and T+ groups using Student t test, Mann-Whitney U test, and χ^2 test. These comparisons were made for all patients (both primary and revision ACLR) as well as for patients who underwent primary ACLR only. Logistic regression analysis was performed to evaluate the impact of older age (≥40 vs <40 years) and tourniquet use on the occurrence of DVT. In the analysis, older age and tourniquet use were used as explanatory variables, and the odds ratios (ORs) with 95% CIs were calculated for these factors. A P value of $< .05$ was considered significant. Statistical analyses were performed with BellCurve for Excel (Social Survey Research Information Co.).

Based on the sample size calculation, assuming a reduction in the incidence of DVT from 16.4% to 1% when converting from tourniquet use to nonuse, with a significance level $\alpha = .05$, 54 knees in each group was needed to achieve a power of 0.8. The sample size calculation was performed with R version 4.0.3 (R Foundation for Statistical Computing).

TABLE 1
Preoperative Clinical and Surgical Demographics of All Patients (N = 115)[a]

	T– Group (n = 60)	T+ Group (Control; n = 55)	*P*
Age, years	27.1 ± 12.1	30.5 ± 15.1	.187
Sex, n			.922
Female	30	28	
Male	30	27	
BMI (kg/m^2)	23.6 ± 3.8	22.6 ± 2.5	.087
D-dimer (μg/mL)	0.07 ± 0.31	0.02 ± 0.18	.350
Current smoking status, n			.899
Smoker	4	4	
Nonsmoker	56	51	
Lysholm score	68.1 ± 15.6	71.1 ± 13.6	.274
Interval from injury to ACLR, n			.471
<3 months	28	22	
≥3 months	32	33	
Type of ACLR, n			.326
Primary	53	45	
Revision	7	10	
Meniscal repair, n			.099
Yes	31	20	
No	29	35	
Preoperative DVT, n	0	0	NA

[a]Data are reported as mean ± SD unless otherwise indicated. ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; DVT, deep venous thrombosis; NA, not applicable; T-, without tourniquet use; T+, with tourniquet use.

RESULTS

There was no significant difference in preoperative clinical and surgical data between the T+ and T– groups overall, and no DVTs were detected preoperatively (Table 1). The mean operative time was not significantly different between the 2 groups, there were no issues with visualization of the surgical field during any of the surgeries, and there were no complications associated with prolonged use of high pump pressure in the T– group. The mean blood loss from the drain was significantly lower in the T- group (149.9 ± 60.3 vs 201.9 ± 76.9 mL for the T+ group; $P < .001$) (Table 2).

TABLE 2
Intra- and Postoperative Characteristics of All Patients (N = 115)[a]

	T– Group (n = 60)	T+ Group (Control; n = 55)	*P*
DVT, n (%)	1 (1.7)	9 (16.4)	**.005**
Operative time, min	78.5 ± 15.1	80.8 ± 18.7	.461
Tourniquet time (min)	NA	68.5 ± 14.7	NA
Blood loss (mL)	149.9 ± 60.3	201.9 ± 76.9	**<.001**
D-dimer (μg/mL)			
POD 1	0.46 ± 0.73	0.57 ± 1.04	.781
POD 7	1.57 ± 1.01	1.66 ± 1.30	.698

[a]Data are reported as mean ± SD unless otherwise indicated. Bold *P* values indicate statistically significant difference between groups ($P < .05$). DVT, deep venous thrombosis; NA, not applicable; POD, postoperative day; T-, without tourniquet use; T+, with tourniquet use.

Postoperatively, DVT was detected in 9 patients (16.4%) in the T+ group and 1 patient (1.7%) in the T– group, for a significantly lower incidence of DVT in the T– group ($P = .005$; power = 0.786) (Table 2). All patients with DVT were asymptomatic. In the T+ group, DVT was found on the operated side in 8 of 9 patients and was located at the soleal vein in 5 patients; peroneal vein in 1 patient; soleal and peroneal veins in 1 patient; and soleal, peroneal, posterior tibial, and popliteus veins in 1 patient. In 1 patient who underwent revision ACLR, the DVT was found in the soleal and the peroneal veins of both legs. In the T– group, DVT was found on the operated side and located at the peroneal and posterior tibial veins. All the DVTs detected in this study were partially occlusive, and there was 1 DVT extending proximal to the knee that was in the popliteal vein. There was no thrombus in superficial veins in any patient.

The patient with the DVTs in the T– group was a healthy 43-year-old man with a BMI of 22.9 kg/m^2 and no factors related to DVT other than older age. After anticoagulation therapy was initiated, the DVTs resolved on ultrasound after a mean of 4.7 weeks (range, 1-12 weeks). No complications associated with anticoagulation therapy, such as bleeding and delayed wound healing, were observed in any patient with DVTs.

When considering just the patients who underwent primary ACLR (n = 98), again there was no difference in patient demographics between the 2 groups (Table 3), and the incidence of DVT was still significantly lower in the T– group (7 patients [15.6%] in the T+ group and 1 patient [1.9%] in the T– group; $P = .014$; power = 0.657) (Table 4).

The logistic regression analysis revealed that age ≥40 years and tourniquet use were significantly related to the occurrence of DVT (OR, 8.3 [95% CI, 1.9-36.8]; $P = .005$; and OR, 8.8 [95% CI, 1.0-75.3]; $P = .047$, respectively).

TABLE 3
Preoperative Clinical and Surgical Demographics of Primary ACLR Patients (n = 98)[a]

	T– Group (n = 53)	T+ Group (Control; n = 45)	*P*
Age, years	27.9 ± 12.5	29.6 ± 14.4	.093
Sex, n			.987
Female	26	22	
Male	27	23	
BMI (kg/m^2)	23.7 ± 4.0	22.9 ± 2.4	.571
D-dimer (μg/mL)	0.08 ± 0.33	0.03 ± 0.20	.388
Current smoking status, n			.809
Smoker	4	4	
Nonsmoker	49	41	
Lysholm score	68.2 ± 15.9	70.9 ± 13.3	.370
Interval from injury to ACLR, n			.349
<3 months	25	17	
≥3 months	28	28	
Meniscal repair, n			.126
Yes	27	16	
No	26	29	

[a]Data are reported as mean ± SD unless otherwise indicated. ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; T-, without tourniquet use; T+, with tourniquet use.

TABLE 4
Intra- and Postoperative Characteristics of Primary ACLR Patients (n = 98)[a]

	T– Group (n = 53)	T+ Group (Control; n = 45)	*P*
DVT, n (%)	1 (1.9)	7 (15.6)	**.014**
Operative time (min)	75.4 ± 13.1	74.4 ± 11.1	.677
Blood loss (ml)	148.2 ± 61.9	194.0 ± 79.4	**.002**
D-dimer, μg/mL			
POD 1	0.52 ± 0.76	0.55 ± 1.11	.641
POD 7	1.63 ± 1.04	1.76 ± 1.36	.600

[a]Data are reported as mean ± SD unless otherwise indicated. Bold *P* values indicate statistically significant difference between groups ($P < .05$). DVT, deep venous thrombosis; POD, postoperative day; T-, without tourniquet use; T+, with tourniquet use.

DISCUSSION

The results of the present study supported our hypothesis that anterior cruciate ligament reconstruction (ACLR) without the use of tourniquet leads to less incidences of deep venous thrombosis (DVT) after ACLR. Those without tourniquet use resulted in a significantly lower incidence of asymptomatic DVT after ACLR and significantly less bleeding from drains, but no difference in operative time. Although more than 2 hours of tourniquet use has been reported to be a risk factor for the development of DVT,[4] this study revealed that tourniquet use itself might be a risk factor for the development of DVT after ACLR. The Virchow triad, including venous stasis, endothelial injury, and hypercoagulability, has been proposed as pathogeneses of DVT.[21] For ACLR, a tourniquet is useful in reducing intra-articular blood loss and improving visualization. However, applying a tourniquet causes venous stasis of the lower extremity, and those who use the device are more

likely to develop asymptomatic DVT identified on routine screening.

Older age,[1,6,9,12,18,20,22,24] hypertension requiring medication,[1] and additional surgery (such as other ligament reconstructions and high tibial osteotomy)[1,4,22] have been reported as risk factors for DVT after ACLR. These factors cannot be controlled by the surgeon to reduce the risk. Pharmacological prophylaxis such as low-molecular-weight heparin is reported to be effective for reducing DVT after ACLR. However, whether the benefits of low-molecular-weight heparin outweigh the risks and costs remains controversial.[3,8,26] According to the American College of Chest Physicians guidelines, pharmacological prophylaxis was not suggested for patients undergoing knee arthroscopy without history of VTE.[5] Whether ACLR is performed with or without a tourniquet is a factor that can be determined by the surgeon. In this study, tourniquet use was revealed to be a risk factor for the development of DVT after ACLR, and there are some reports of neuromuscular complications with the use of a tourniquet.[16,19] If adequate visibility of the surgical field is secured, ACLR without tourniquet use should be considered.

The management of asymptomatic distal DVT identified on routine scanning is still controversial. Distal DVT is reported to be associated with a high incidence of PE comparable with that of proximal DVT,[13] and some institutions have administered anticoagulation therapy for asymptomatic distal DVT detected by screening.[20,24] In our hospital, we provided anticoagulation therapy even for asymptomatic DVT in order to prevent DVT from developing into life-threatening PE and to avoid post-thrombotic syndrome.

Since the arthroscopic visibility was reported to be impaired without the use of a tourniquet due to bleeding in the surgical field,[7] there was a concern that ACLR without tourniquet use may prolong the operative time due to the need for hemostatic maneuvers to secure the operative field. However, there was no significant difference between the T+ and the T– groups in this study. Similar results have been reported previously.[14,25] We believe that this result can be attributed to, among other factors, the appropriate use of an irrigation pump and a radio frequency device to control intra-articular hemorrhage and to secure an operative visualization even without the use of a tourniquet. As with previous reports, those without tourniquet use in this study resulted in significantly less blood loss from drains.[14,19] This was thought to be a result of the bleeding site, which could be identified, and hemostasis, which could be achieved by radio frequency device in ACLR without the use of a tourniquet.

We included patients who underwent both primary ACLR and revision ACLR in this study. The differences between the primary and revision ACLR at our hospital were that, for the revision procedure, the graft tendon was harvested from the contralateral side and the staples placed during the primary ACLR needed to be extracted. The procedures related to the occurrence of DVT were considered to be almost the same between primary and revision ACLR in this study, and revision ACLR was not reported to influence the risk of VTE.[12] The incidence of DVT was investigated among primary and revision ACLR together, and the statistical power reached 0.786, approaching the appropriate level. Just to be sure, the incidence was examined among those who underwent primary ACLR alone, and the results were almost the same as when revision ACLR was included.

At our hospital, the length of stay exceeded 1 week after ACLR, which was different from the international current practice of ACLR's being a day surgery or needing only a single night's stay. If the patients were able to walk, even with crutches, they were allowed to leave, but many chose to stay at our hospital for the full 7 days allowed by our nation's healthcare system. In previous reports, there have been facilities where patients have been hospitalized for about a week after ACLR.[15,22,24] We believe that different insurance systems, number of available beds, and other factors throughout the world lead to different lengths of hospital stay after ACLR.

This study has some limitations. First, it included a small number of patients. Second, the comparison of intraoperative blood loss between ACLR with and without tourniquet use could not be performed. While the tourniquet was used to secure the surgical visualization rather than to control bleeding, comparison of postoperative blood loss between the 2 groups was conducted as one of the evaluations of the use of tourniquet. Third, postoperative development of a hemarthrosis is a concern, but it was not evaluated in this study. Fourth, although the localization of the DVT was diagnosed by ultrasound, the length of the DVT was not measured.

CONCLUSION

In this study, patients who did not have a tourniquet had a significantly lower incidence of asymptomatic DVT after ACLR and significantly less bleeding from drains, although there was no difference in operative time. If adequate visibility of the surgical field is secured, ACLR without tourniquet should be considered as a viable option.

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