Original Article

Blood Loss in TKA with Tourniquet Release Before and After Wound Closure

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Objective: To compare measured blood loss in total knee arthroplasty [TKA] with tourniquet release before and after wound closure.

Materials and Methods: Sixty-four osteoarthritic knee patients undergoing TKA were randomly assigned to one of two groups. In one group, the tourniquet was released before a polyethylene insert was put in place (Before Group) and in the other, release occurred after wound closure (After Group). Tourniquet pressure was set at patient systolic blood pressure plus 150 mmHg. A suction drain was placed and retained for 48 hours postoperatively. Measured blood loss, blood drainage, 24-hour postoperative fall in hematocrit, change of hematocrit, and rate of blood transfusion were measured. Wound complications, deep vein thrombosis, and knee flexion were also recorded. All patients were followed for at least three months.

Results: Mean total blood loss was similar between the two groups (377±155 in the Before Group and 450±172 mL in the After Group, $p = 0.09$). Patients in the Before Group had less blood loss in the drain but they had an average additional intraoperative blood loss of approximately 72±53 mL. Change in hematocrit was not different between the groups (7.8% in the Before Group and 8.4% in the After Group, $p = 0.45$). Fewer patients in the Before Group required blood transfusion (30% versus 48%, $p = 0.001$). There were no wound complications or deep-venous thrombosis in either group. Postoperative knee flexion was also similar in both groups.

Conclusion: Releasing the tourniquet before wound closure does not change postoperative total blood loss compared with after wound closure, but it does reduce postoperative blood loss collected in the drain.

Keywords: Blood loss, Suction drain, Tourniquet, Total knee arthroplasty

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The use of a pneumatic tourniquet during total knee arthroplasty [TKA] is a common practice. The benefits of a tourniquet that have been widely recognized are the reduced blood loss, improved visualization of structures, and better cementation[1,2]. Some authors have recommended tourniquet release before wound closure to limit potential adverse effects and to achieve hemostasis sooner[3,4]. Others have advocated releasing the tourniquet after wound closure and dressing because there was no difference in postoperative complications or in blood loss, or even an increase in blood loss with early tourniquet release[5,6]. Release of the tourniquet before or after wound closure is still debated and there have been only a limited number of well-designed randomized controlled trials addressing this controversial issue.

The aim of the present study was to compare tourniquet release before and after wound closure using measured postoperative blood loss after primary TKA in a prospective, randomized, double-blind controlled trial. The authors hypothesized that tourniquet release before wound closure would reduce postoperative blood loss compared with release after wound closure.

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Materials and Methods

Sixty-four osteoarthritic knee patients (64 knees) who underwent primary TKA at Thammasat University Hospital between August 2012 and June 2013 were recruited. Ethical approval of the present study was obtained from the Institutional Review Board of Thammasat University Hospital (MTU-E-1-71/52). Written informed consent was received from all patients. The inclusion criteria were a diagnosis of primary osteoarthritis and age between 50 and 90 years. The exclusion criteria were renal impairment (creatinine clearance greater than 30 mL/minute), coagulation disorder, and discontinuance of anti-platelet medication fewer than seven days before surgery. All patients were randomly assigned to one of two groups using a computer randomization program.

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Table 1. Patient demographic data at recruitment

	Before wound closure group (n = 30)	After wound closure group (n = 31)	*p*-value
Mean age (years)	68.7±8.9	68.6±7.4	0.97
Sex (male/female), n	3/27	3/28	-
Side of knee (right/left), n	15/15	19/12	-
Mean height (cm)	159±6	158±6	0.64
Mean weight (kg)	66±10.1	65±9.6	0.83
Body mass index (kg/m^2)	26±3.7	25.9±3.7	0.95
Preoperative HKA (degrees)	172.7±4.1	174.3±7.5	0.29
Tourniquet pressure (mmHg)	260±10	259±14	0.83
Tourniquet time (minutes)	74±14	107±14	-
Operative time (minutes)	115±14	107±14	0.16

HKA = hip-knee-ankle

Data presented as mean ± SD

In one group, the Before Group, the tourniquet was released after implants had been cemented and just before the real polyethylene insert was put in place; in the other group, the After Group, release was done after wound closure. Group allocation was concealed in an opaque envelope. Both groups were demographically similar (Table 1). Three knees were excluded from analysis because of drain dislodgement within 48 hours after surgery (Figure 1).

The authors used a standard AO tourniquet system. The tourniquet was wrapped around the upper thigh over a layer of cast padding. An Esmarch bandage was used to exsanguinate the lower limb. The tourniquet pressure was set equal to patients' systolic blood pressure level plus 150 mmHg. One surgeon (Tammachote N) operated on all the knees under spinal anesthesia without awareness of group allocation. All knees were implanted using the Genesis II® (Smith & Nephew, Memphis, Tennessee) posterior stabilized knee system with high flex polyethylene insert.

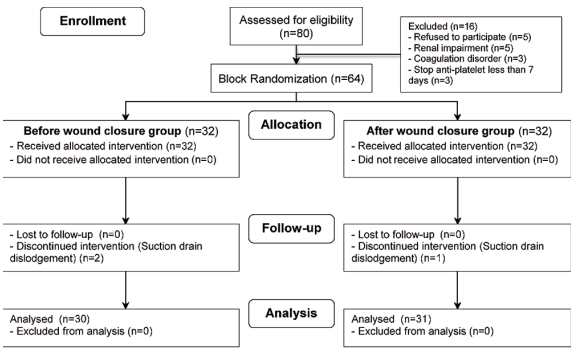

Figure 1. The flow chart shows the protocol of the present study.

A conventional approach with midline skin incision was done at medial edge of the quadriceps tendon down to the medial side of the tibial tubercle along with standard medial parapatellar arthrotomy. Electric cautery was used to stop bleeding during this phase of the operation. The deep part of the medial collateral ligament was peeled off from the posteromedial aspect of the medial tibial plateau. The patella was everted. An intramedullary femoral cutting guide was used. An extramedullary tibial cutting guide was used. The distal cut was made first, then the anterior-posterior [AP] dimension of femur was measured, and the AP femoral cut was made. The tibia was pushed forward, and an extramedullary tibial cutting guide was used to make the tibial cut perpendicular to the mechanical axis. A posterior osteophyte on the femur was removed using a curved osteotome. Flexion and extension gaps were balanced medially and laterally. None of the knees had the superficial medial collateral ligament released by the Cobb osteotome or by lateral retinacular release. The tibia was measured, and the femoral chamfer cut was accomplished. None of the patellae were resurfaced. The patellar osteophyte was removed using a rongeur. A bone plug was inserted into the femoral hole. The bony surface was cleaned by pulsatile lavage. The prosthesis components were inserted with antibiotic cement (Simplex®, Stryker), first at the tibia then the femur. An anesthetic cocktail (5 mg of morphine sulfate, 0.6 mg of 1:1,000 epinephrine, 20 mL of 0.5% bupivacaine, 30 mg of ketorolac and mixed with normal saline up to 100 mL) was injected into the posterior joint capsule (approximately 25 mL) before implantation of the real component and the rest (75 mL) was injected around the quadriceps muscle, joint capsule, pes anserinus, and the infra and supra-patellar fat pat while waiting for the cement to cure.

The sealed envelopes were opened after the implant had been cemented. In the Before Group, the tourniquet was released prior to putting the real polyethylene insert in place. Bleeding points were coagulated, and intraoperative blood loss was measured by weighing the gauze. In the After Group, the tourniquet was released following wound closure. None of the legs were wrapped with compressive dressing. Patients and the evaluator were blinded.

All patients had a suction drain placed within the knee joint capsule. None of the drains were clamped. Drainage was recorded until the drain was removed 48 hours after surgery. The hematocrit was obtained from

a complete blood count test and recorded at 24 hours postoperatively. Urine specific gravity and vital signs were used to monitor patients' hemodynamic status. Blood transfusions were given if the hematocrit level at 24 hours was less than 30%. No drugs were given for deep vein thrombosis prophylaxis.

The same rehabilitation protocol was followed with all patients. Each patient ambulated with a walker the morning after surgery. Immediate full weight bearing and isometric quadriceps exercises were initiated. The foot pump exercised was encouraged. All patients met the criteria to be discharged at postoperative day 3, which included independent ambulation with a walker for 20 meters, bending the knees approximately 90 degrees at bedside, pain well controlled by oral medication, and no wound complications. Routine follow-up was done at two weeks, six weeks, and three months postoperatively.

Primary outcomes were measured blood loss, postoperative fall in hematocrit at 24 hours, change in hematocrit, and rate of blood transfusion. Measured blood loss was the sum of intraoperative bleeding and blood loss collected in the suction drain. Secondary outcomes were hematocrit at 24 hours, change in hematocrit, rate of blood transfusion, wound complications, rate of deep vein thrombosis, and knee flexion measured at 12 weeks after surgery. Wound complications noted included wound discharge, wound dehiscence, and wound infection. Deep vein thrombosis was clinically assessed at the initial follow-up. Knee flexion was measured using a goniometer.

Statistical analysis was carried out using SPSS for Windows version 15 (SPSS Inc., IL, USA). The t-test was used to compare the mean differences of in blood loss in the drain and measured blood loss; Fisher's exact test was used for categorical variables. Differences were considered statistically significant when *p*-value was smaller than 0.05. The sample size was calculated to detect a minimum difference of 150 mL of measured blood loss between the two groups with a standard deviation 200 mL[7]. Twenty-eight patients in each group were required to detect the expected difference with an 80% power at a 5% two-tailed significance level. The authors anticipated a dropout rate of about 15%, so 64 patients were included in the present study.

Results

Mean measured blood loss was similar between the groups (377±155 mL in the Before Group and 450±172 mL in the After Group, $p = 0.09$). Mean collected blood loss in the drain was 305±158 mL in the Before Group and 450 ±172 mL in the After Group ($p = 0.001$). The Before Group had a mean additional intraoperative blood loss of approximately 72±53 mL (Table 2). Mean 24-hour postoperative hematocrit was higher in the Before Group (31% versus 29%, $p = 0.01$), but no difference was detected in hematocrit change between the two groups (8% versus 8%, $p = 0.45$). Nine patients (30%) received blood transfusions in the Before Group, while 15 patients (48%) in the After Group received blood transfusions ($p = 0.001$).

There were no wound complications or incidents of deep-venous thrombosis in either group. The outcomes at three months postoperative revealed no difference in knee flexion between the groups ($p = 0.52$).

Discussion

Using a pneumatic tourniquet during TKA allows for blood conservation, provides a clean and dry operative field, provides benefits during cementing, and shortens surgical time[5]. The use of a tourniquet is a safe and popular current practice[2]. There is, however, still controversy about the timing of release of the tourniquet. One approach releases the tourniquet before

Table 2. Outcome measurements in "Before" and "After" wound closure tourniquet release groups

	Before wound closure group (n = 30)	After wound closure group (n = 31)	*p*-value
Blood in suction drain (mL)	305±158	450±172	0.001
Total measured blood loss (blood loss in drain + intraoperative blood loss) (mL)	377±155	450±172	0.09
Number of patients requiring blood transfusion, n (%)	9 (30)	15 (48)	0.001
24-hour postoperative hematocrit level (%)	30.7±3.6	28.6±3	0.01
Change in hematocrit level (%)	7.8±2.7	8.4±2.7	0.45
Wound complications	0	0	-
Deep vein thrombosis	0	0	-
Postoperative knee flexion at 12 weeks (degrees)	133±10	130±10	0.52

Data presented as means ± SD

Table 3. Summary of previous clinical trials addressing tourniquet release timing

Study	Number of knees		Prosthesis	Tourniquet		Blood loss							Rate of blood transfusion	
				Pressure	When deflated	Intraoperative		Drain		Drain removed	TBL		CBL			
	Early	Late				Early	Late	Early	Late		Early	Late	Early	Late	Early	Late
Newman et al.[9]	42	42	NR	NR	Before wound closure	NR	NR	NR	NR	NR	883	692	NR	NR	NR	NR
Barwell et al.[3]	44	44	Cemented	NR	Before quadriceps closure	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Widman and Isacson[11]	46	39	Cemented	300 to 350	Before wound closure	256	-	777	985	24 hours	1,026	985	NR	NR	276	280
Jorn et al.[6]	42	35	Cemented/ cementless	300	Before wound closure	221	-	637	589	24 hours	858*	589	NR	NR	40%	29%
Christodoulou et al.[7]	40	40	Cemented/ hybrid tibia	125 to 150 above SBP	Before wound closure	226	-	NR	NR	2nd day	961*	692	NR	NR	4.7 units*	4.0 units
Hersekli et al.[5]	41	41	Cemented	350 to 400	All component inserted	NR	-	881*	745	24 hours	NR	NR	NR	NR	76% (484)	61% (380)
Ishii and Matsuda[14]	30	30	Cementless	100 above SBP	Before wound closure	269	Trace	638	731	1st day	906*	731	1,066*	840	0%	0%
Valenti et al.[33]	97	97	Cemented	350	Before PE inserted	NR	NR	562	488	At 24 hours	721	625	NR	NR	62%	59%
Hernández-Castaños and Gil[13]	23	23	NR	100 above median arterial pressure	Before wound closure	NR	NR	NR	NR	<20 ml in 24 hours	743	693	NR	NR	2 units	1.8 units
Yavarikia et al.[34]	36	29	NR	220 to 275	All component inserted	NR	-	720	705	After 24 hours	NR	NR	NR	NR	241	239
Present study	30	31	Cemented	150 above SBP	Before PE inserted	72	-	305	450*	At 48 hours	377	450	NR	NR	30%	48%*

TBL = total blood loss; CBL = calculate total blood loss; SBP = systolic blood pressure; PE = polyethylene; NR = not reported in the study

* Statistically significant

wound closure, while another releases it after wound closure and application of a compressive dressing. Our objective was to determine whether releasing the tourniquet before or after wound closure results in less postoperative measured blood loss. In the present study, there was no difference between early and late release of the tourniquet in measured blood loss or change in hematocrit 24 hours after surgery. Blood transfusion was lower in the Before Group (30% versus 48%). There were no wound complications, DVT, or postoperative knee flexion problems in any patients.

Results of the few published well-designed randomized studies evaluating the timing of tourniquet release are shown in Table 3. Results of those studies are not conclusive. One study found late release of the tourniquet had no effect on operating time and patients had lower hemoglobin levels at 48 hours postoperatively compared with early release; however, the early release group had less postoperative pain, better range of motion, and fewer wound complications[3]. Other studies have reported that releasing the tourniquet prior to wound closure does not reduce either blood loss or transfusion rate[8-11]. A recent meta-analysis reported that early release of the tourniquet increased perioperative blood loss, while late release of the tourniquet (after wound closure) had a higher rate of additional surgery[12]. However, some studies that do not support tourniquet release for hemostasis, reported that releasing the tourniquet after wound closure decreased measured blood loss[6,7,11,13,14]. They claimed that control of fibrinolytic activity and activation of coagulation factors might be improved when the tourniquet was applied until the compressive dressing was completed. Reactive hyperemia and fibrinolytic activity might increase in a few minutes after the tourniquet is released if the release occurs before the compressive dressing is put in place[15,16]. A local compressive effect achieved by closing the wound and firmly applying the dressing might be able to control this bleeding.

In the present study, the Before Group had lower collected blood loss in the drain than the After Group. These data are in line with those reported by Widman and Isacson[11] and Ishii and Matsuda[14] who found that blood loss in the drain was lower in the early release group. That reduction of blood loss was successfully achieved by stimulating coagulation in potential bleeders by releasing the tourniquet intraoperatively. One recent study concluded that hidden blood loss can be reduced by hemostasis with an intraoperatively released tourniquet[17].

The authors standardized factors that might affect blood loss such as thromboembolic prophylaxis, cementing technique, drainage-cramping technique, and postoperative care protocol. An early postoperative rehabilitation protocol is another factor that may influence blood loss in intraoperative tourniquet release patients. One study found significantly higher blood loss when a continuous passive motion [CPM] machine was started immediately in the recovery room than when it was started on the third day postoperatively[18]. The authors did not use a CPM machine for any of the study patients, but the authors did encourage range of motion exercise as tolerated while patients sat on the edge of their beds.

It is notable that the overall blood transfusion rate in our study was quite high (39%). Other studies have reported rates between 11% and 95%[19]. Although in orthopedics and trauma surgery the accepted blood transfusion threshold has been lowered to 8 g/dL of hemoglobin or 24% of hematocrit in elderly patients without major comorbidities[20], significant increases in 90-day post TKA operative cardiovascular complications in patient older than 65 years have been reported[21]. For that reason, the authors gave blood transfusions to the patients whose hematocrit was less than 30% at 24 hours post operation instead of waiting until the hematocrit dropped to 24%.

Previous studies have reported that using a tourniquet may increase the risk of cardiopulmonary dysfunction, vascular injury, deep vein thrombosis, delayed wound healing, and nerve damage[18]. To minimize these complications, the preferred practice is to reduce tourniquet pressure as much as possible and to minimize the compression time. Tourniquet inflation pressures have been documented ranging from 125 to 400 mmHg[22-28]. In the present study, the tourniquet pressure was set at 150 mmHg above systolic blood pressure, which provides adequate control of hemostasis. Because a low-pressure and short duration tourniquet was applied, there were no wound complications, deep venous thrombosis, or nerve injury in either group.

The present study has a number of limitations. First, the authors did not calculate total blood loss [CBL] as recommended by the Gross method[29]. Although CBL was reportedly designed to measure actual total blood in some publications, it has not been widely used in clinical practice[30]. Some studies have used hematocrit at two or three days post-operation to calculate the perioperative blood loss, while others have calculated total blood loss from the maximum hemoglobin drop after surgery[31,32]. For those reasons, the authors focused on the effect of tourniquet release on blood loss collected in the suction drain over 48 hours which is a more practical and accurate measure in clinical practice than CBL. Second, the authors used the 24 hours postoperative hematocrit to determine the need for blood transfusion. The authors routinely monitored vital signs and urine output to maintain the hemodynamic status of the patient postoperatively. Crystalloid fluid was used to replace patient blood loss. Urine specific gravity was monitored, and patient blood volume deficit was replaced. Foley catheters were removed at 24 hours postoperatively. If hematocrit was less than 30% with normal urine specific gravity (less than 1.020), blood transfusion was ordered. All patients were discharged the morning of postoperative day 3.

In conclusion, releasing the tourniquet before wound closure does not change postoperative measured blood loss compared with release after wound closure, but it does reduce postoperative blood loss collected in the drain.

What is already known on this topic?

The issue about tourniquet and blood loss is always interesting. Many studies reported variation of outcomes. There were limited well design randomized studies that evaluated the timing of tourniquet released, and the results have been debatable. The recent meta-analysis showed that early release of tourniquet increased perioperative blood loss while late releasing tourniquet after wound closure had higher rate of additional surgery. However, there were some studies against the efficacy of tourniquet released for hemostasis, they reported that releasing tourniquet after wound closure decrease measured blood loss.

What this study adds?

This study showed a clear primary outcome even if it is non-significant. Releasing the tourniquet before wound closure did not change postoperative total blood loss compared with after wound closure. However, it reduced postoperative blood loss collected in drain.

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Potential conflicts of interest

The authors declare no conflict of interest

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