



## Original research

## Tourniquet and tranexamic acid use in total knee arthroplasty

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## ABSTRACT

**Background:** There is no consensus on how tourniquet and tranexamic acid (TXA) use in total knee arthroplasty (TKA) affect blood transfusion rates and total blood loss. We compared outcome measures and transfusion rates after TKA, with and without the use of tourniquet and TXA.

**Methods:** A retrospective study of 477 consecutive patients undergoing primary TKA between 2008 and 2013 was performed. There were 243 in the tourniquet-assisted (TA) and 234 in the tourniquet-unassisted (TU) group. Operative times, hemoglobin levels, blood transfusion rates, complications, and length of stay were assessed. Subanalysis was performed on those patients receiving and not receiving TXA within the TU group.

**Results:** Mean operative duration was 66.4 minutes in the TA group and 87.5 minutes in the TU group ( $P < .0001$ ). Mean postoperative drop in hemoglobin was greater in TU group (3.1 g/dL vs 2.8 g/dL,  $P = .002$ ). The transfusion rate was 9.5% in TA compared with 11.5% in TU patients ( $P = .46$ ) with comparable mean units transfused (2.6 vs 2.2,  $P = .30$ ). There was no difference in wound infection ( $P = .82$ ) and total complication rates ( $P = .27$ ) between groups. Those patients given TXA had a lower hemoglobin drop (2.6 g/dL vs 3.3 g/dL,  $P = .04$ ) with similar transfusion (13.3% vs 11%,  $P = .61$ ) and complication ( $P = .95$ ) rates.

**Conclusions:** TU TKA had a greater operative duration and postoperative drop in hemoglobin than TA TKA. However, transfusion rates were similar between groups. TXA use reduced the operative decrease in hemoglobin with no effect on complication or transfusion rates.

**Level of Evidence:** Level III, retrospective cohort study.

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## Introduction

Worldwide, the geriatric population is growing [1]. One consequence of this growth is a prediction that 1–3.5 million total knee arthroplasty (TKA) procedures will be performed throughout the United States in the year 2030 [2,3]. TKA is associated with significant blood loss, which may necessitate blood transfusion. Mean total blood loss in TKA has been reported as high as 1400–1500 mL, or over 30% of the body's total blood volume [4,5]. Furthermore, the concept of “hidden blood loss” (total blood loss subtracted by measured blood loss) has become better understood with recurrent study and has been reported as high as 49% of total blood loss in

TKA by Sehat et al [6]. This degree of blood loss can result in prolonged postoperative recovery, lengthened hospital stay [7], increased morbidity [8], and requirement of risk-plagued transfusion [9–11] in as high as 60% of cases [10].

With total blood loss reduction and improved intraoperative visualization in mind, tourniquets have been widely used during TKA. A historical review of practice patterns demonstrated tourniquet use in 95% of cases in the absence of vascular disease [12], although recent data suggest this number may be lower now [13,14]. Nevertheless, tourniquets have been shown to improve intraoperative visibility [15–17], reduce intraoperative blood loss [18,19] and transfusion rates [18,20], and decrease total operative time when released after wound closure and dressing application [17].

However, tourniquet use is not without risks. It has been associated with increased incidence of postoperative nerve palsies [21,22], thigh pain [13,23,24], muscle necrosis [25], rhabdomyolysis [26,27], pathologic patellofemoral tracking [28], early infection

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[29], and lower postoperative quadriceps muscle strength [30]. Perhaps the most notable adverse outcome associated with tourniquet use is a heightened risk of venous thromboembolism [31]. For example, a meta-analysis by Jiang et al [18] showed a DVT incidence of 25.3% after TKA in cases in which a tourniquet was used compared with 17.7% without tourniquet. It is also hypothesized that tourniquet use may be related to increased hidden blood loss when used for TKA [6,32]. If a tourniquet is kept inflated throughout the procedure, measured blood loss is negligible, but reperfusion hyperemia occurs after wound closure, potentially negating the positive effects of a bloodless surgical field. Tourniquet use has been shown to accelerate fibrinolysis because of increased release of tissue plasminogen activator from endothelium after associated trauma [33–35] and ischemia [36]. This tourniquet-induced enhanced fibrinolytic activity [34,37,38] may promote bleeding into the local tissues (ie, hematoma) after the procedure.

Tranexamic acid (TXA) has become commonly used agent used to reduce blood loss in trauma, cardiac, and orthopaedic procedures and has been shown to reduce blood transfusion after TKA. TXA inhibits fibrinolysis by competitive inhibition of a lysine-binding site of plasminogen. This inhibits the conversion of plasminogen to the active fibrinolytic enzyme, plasmin, thus stabilizing blood clots [39] and reducing bleeding. A meta-analysis by Yang et al [40] found that TXA administration in TKA reduced blood loss by an average of 500 mL when compared with placebo. Another prospective randomized controlled trial demonstrated significantly reduced postoperative blood loss and number of transfusions in TXA-treated patients [41,42] receiving tourniquet-assisted (TA) TKA.

Although both tourniquets and TXA have been studied individually, there is a paucity of data examining outcomes with the use of both interventions together. Huang et al [43] demonstrated that patients treated with multiple doses of IV and topical TXA without a tourniquet had less hidden blood loss and better early knee function than those patients who were treated with a tourniquet in addition to TXA. There was, however, no significant difference in total blood loss or transfusion rate. Nonetheless, additional study is necessary to gain further insight into the blood-saving role of both tourniquet and TXA use together in TKA.

Our study aims to expand on prior findings. Specifically, the primary objective was to compare outcomes (operative duration, hemoglobin levels, rate of blood transfusion, medical/surgical complications, and length of hospital stay) after TA and tourniquet-unassisted (TU) TKA. The secondary objective was to assess the influence of TXA on these outcomes in the unassisted TKA cohort.

## Materials and methods

This was a retrospective cohort study of 477 consecutive patients undergoing primary TKA at a district general hospital in the United Kingdom over a 5-year period. Two senior, high-volume fellowship trained hip and knee orthopaedic surgeons performed the surgeries: one used a tourniquet and the other did not. TXA was administered only in the TU group in the absence of contraindications including a history of allergy to TXA, altered color vision, intracranial bleeding, thrombophilia, cancer, heart disease, stroke,

venous thromboembolism, and renal dysfunction [44,45]. Exclusion criteria were revision TKA, no data on tourniquet, and TXA use.

## Operative details

All patients were seen in the outpatient clinic with significant knee pain and dysfunction, with Kellgren-Lawrence [46] grade 3 or 4 and changes on radiographs. Patients had exhausted nonoperative treatment including activity modification, nonsteroidal anti-inflammatory drugs, and physical therapy. They were considered medically acceptable to undergo TKA, with a minimum preoperative hemoglobin >10 g/dL.

The TKA procedure was performed under neuraxial anesthesia with sedation, and intravenous prophylactic cefuroxime was given within 30 minutes of the incision. In the cases in which TXA was used, 1 g of intravenous TXA was given immediately before incision, with another 1 gram administered at the start of closure. The approach was a midline incision followed by a standard parapatellar approach. All knees were Vanguard posterior-stabilized (Zimmer Biomet, Warsaw, IN) implants, which were cemented with PALACOS R + G (Heraeus, Germany) bone cement, which contains 0.50 g of gentamicin per 40.8 g pack. In the TA group, a high-thigh tourniquet was applied and inflated at 300 mm Hg due to surgeon preference after elevation exsanguination, and it was released after closure and application of dressings at the end of the case. No surgical drains were used in the cases. All patients received subcutaneous enoxaparin once a day for thromboprophylaxis in addition to compression stockings for 14 days. Patients were mobilized with physical therapy beginning on the day of surgery and were discharged once they were medically stable and met modified independent mobility goals for safe discharge. If rehabilitation was required, this was performed in hospital. Routine laboratory tests, including a hemoglobin level, were performed at day 1 postoperatively in all patients. Further hemoglobin levels were taken according to clinical need during the hospital stay, but only the postoperative day 1 hemoglobin values were used in analysis of perioperative blood loss. The institutional transfusion threshold was a hemoglobin level of 8 g/dL, with significant symptoms and signs of anemia, unless there was a history of cardiac disease, with the number of units according to clinical need. Scheduled clinical and radiologic follow-up intervals were at 2, 6, 12, 36, and 52 weeks postoperatively.

## Data collection and analysis

Institutional IRB approval was granted to complete the study. A consecutive list of all TKAs performed by the 2 senior authors between 2008 and 2013 was obtained from the institutional clinical coding department. Medical records were reviewed for all patients to confirm eligibility, obtain the baseline characteristics (Table 1), and operative/postoperative details. Operative details were recorded by the primary surgeon and anesthesiologist and included the operative time (incision time to application of dressings, in minutes) and blood loss (in milliliters). Postoperative details recorded included the number of packed red blood cells transfused and complications during the inpatient stay. Data on complications included surgical complications: infection, hematoma formation, postoperative nerve palsies, need for revision, and medical complications: gastrointestinal bleeding, pulmonary infections, myocardial infarction, and acute renal dysfunction. Patient baseline demographics and outcomes were compared between the 2 groups. Further subanalysis was performed to compare the baseline demographics and outcomes between those receiving and not receiving TXA within the TU group.

**Table 1**  
Baseline demographics between the 2 groups.

Variable	TA	TU	P value
n	243	234	
Male sex	70 (%)	89 (%)	.03
Mean age (years)	71.3 (50-90)	71.9 (49-87)	.51
Mean length of stay (days)	5.8 (2-64)	7 (2-67)	.07
Mean preoperative hemoglobin (g/dL)	13.2 (9-16.2)	13.1 (9.5-15.7)	.44

**Table 2**  
Comparison of outcomes between the 2 groups.

Variable	TA	TU	P-value
n	243	234	
Mean operative duration (minutes)	66.4 (30-135)	87.5 (43-162)	<.0001
Mean hemoglobin drop (g/dL)	2.8 (0.3-6.1)	3.1 (0-6.1)	.002
Total patients transfused (%)	23 (9.5)	27 (11.5)	.46
Mean units of blood transfused	2.6 (1-7)	2.2 (1-4)	.3

Statistical analysis was completed using SPSS 22.0 for Windows (SPSS Inc., Chicago, IL). Student's *t*-test and Wilcoxon-Mann-Whitney tests (continuous variables) and Pearson's chi-squared/Fisher's exact tests (categorical variables) were used to determine differences in the baseline demographics and outcomes between groups. A *P* value of  $\leq 0.05$  was considered statistically significant.

## Results

The data of 477 consecutive patients undergoing primary TKA was available, with no patients excluded. There were 243 patients in the TA and 234 patients in the TU group. The baseline characteristics are shown in Table 1. Of note, there were significantly more males ( $P = .03$ ) in the TU group.

As shown in Table 2, mean operative duration was 66.4 minutes (30-135) in the TA group and 87.5 minutes (43-162) in the TU group ( $P < .0001$ ). Mean drop in hemoglobin was also lower in the TA group ( $P = .002$ ), but there were no differences in number of transfusions or the mean number of units of blood transfused between the 2 groups. There were no differences seen in the rate of surgical or medical complications (Table 3).

### Tranexamic acid in the tourniquet-unassisted group

Use of TXA resulted in a significant ( $P = .04$ ) reduction in hemoglobin drop compared with no TXA use within the TU group. However, there was no difference in transfusion rates or complications with or without TXA administration (Table 4).

## Discussion

Extensive blood loss is an important complication of TKA. With the increasing prevalence of TKA [2,3], it is imperative that the orthopaedic community fully understand the utility and efficacy of various blood-saving techniques. Our study found that TA TKA reduced perioperative hemoglobin drop and mean operative duration compared with TU TKA. Tourniquet use, however, did not influence need for postoperative blood transfusion and was not associated with a higher rate of medical or surgical complications. TXA reduced postoperative drop in hemoglobin, but had no effect

**Table 3**  
Comparison of complication rates between the 2 groups.

Variable	TA	TU	P Value
Surgical complications			
Surgical site infection	2	0	.59
Deep infection/revision	3	2	.69
Hematoma	0	1	.54
Wound dehiscence	0	1	.54
Medical complications			
Respiratory tract infection	0	3	.29
Acute coronary syndrome	0	3	.29
Acute kidney disease	0	1	.54
Gastrointestinal bleed	1	0	.54
Total (%)	6 (2.5)	10 (4.3)	.27

**Table 4**  
Subanalysis comparing outcomes with and without tranexamic acid (TXA) in the tourniquet-unassisted (TU) group.

Variable	TXA	No TXA	P-value
n	60	174	
Mean hemoglobin drop (g/dL)	2.6 (0.3-6.1)	3.3 (0-6.1)	.04
Total patients transfused (%)	8 (13.3)	9 (11)	.61
Mean units of blood transfused	2.8 (1-9)	2 (1-2)	.2
Total complication rate (%)	3.3	5.2	.95

on complication or transfusion rates. This study advances understanding of the 2 principal blood saving techniques used in TKA, which will assist orthopaedic surgeons in reducing complications [8] that can occur with blood loss. Furthermore, it suggests a favorable safety profile with TXA use and limited clinical benefit to justify routine tourniquet use in TKA.

Our study demonstrated that tourniquet use during TKA resulted in a shorter total operative time. Although tourniquet use has been historically routine in most TKA cases [12], owing to improved intraoperative visibility among other benefits [15], there has been a recent trend in TU TKA with the goal of improving pain and function scores while minimizing complication rates. Tourniquet use provides a bloodless surgical field which has some technical advantages, and the fiscal impact of saving 20 minutes per procedure with tourniquet use has significant economic benefits for health care systems, as operating room time is costly. In addition, tourniquet use facilitates preparation of drier bone surfaces for cementing, which can theoretically affect cement penetration into periprosthetic bone [23], thereby enhancing initial and long-term fixation and survivorship [23,47,48]. This rationale can influence the surgeon's decision to use a tourniquet; however, studies have failed to show differences in tibial cement penetration or long-term implant survival attributable to tourniquet use in TKA [14,49,50].

The present study demonstrated that TA TKA showed a significantly smaller drop in pre- to post-operative hemoglobin compared with TU TKA. This finding is consistent with prior literature demonstrating the effectiveness of tourniquet use in reducing intraoperative blood loss [18,19,51]. The true relationship between tourniquet use and transfusion rates in TKA has been a topic of much debate with numerous conflicting results [18,20,52-54]. Our study showed no significant difference in transfusion rates between TA and TU groups, consistent with the findings of Wang et al [54] and Zhang et al [16]. Hidden blood loss is likely responsible for the lack of differences seen between TA and TU groups in our study. Improved understanding of the role of hidden blood loss has led some surgeons to release the tourniquet to obtain hemostasis before wound closure [55].

There are further distinct disadvantages to using tourniquets for TKA. Although we did not assess pain and other clinical outcome scores, tourniquet use has been implicated as cause for higher thigh pain scores [14,17,56], delayed recovery and rehabilitation [57], and poorer functional outcomes up to 1 year after surgery [57]. Furthermore, tourniquet use has been linked to increased analgesic requirement by patients postoperatively [57], thus placing patients at heightened risk of opioid-related complications and contributing to our nation's current epidemic. Related to this is hospital length of stay, which was not significantly different between the 2 groups, although admittedly longer compared with routine practice today in the United States. This may reflect historical practices where longer hospital stays were more routine with rehabilitation performed in the hospital setting rather than a dedicated center. In addition, the data may have been skewed by patients with medical complications requiring a longer hospital stay.

TXA, administered in topical, oral, or intravenous forms, has gained general popularity among orthopaedic surgeons. It may be especially important with concomitant tourniquet use, as the associated trauma and ischemia are believed to further accelerate the process of fibrinolysis [34–36]. There is strong evidence to support that TXA use both lowers total blood loss and transfusion requirement after primary TKA [58]. Although the present study demonstrated a significant reduction in pre- to post-operative hemoglobin drop within the TU group, there was no significant difference in rate of transfusion with or without TXA, in contrast to other published studies [18,20]. One potential reason for this is that the greater degree of hemoglobin drop shown in patients not given TXA was not enough to reach the institution's transfusion guidelines on transfusion cutoff thresholds.

Previously, orthopaedic surgeons were hesitant to adopt TXA into practice because of poorly supported links to venous thromboembolic events, acute renal failure, and stroke. Contraindications to TXA use has been a topic of much debate, and large-scale database studies have found no increased complication risk when TXA was administered to patients with relative contraindications [59–62]. Despite a comparatively small sample size, our study substantiated prior findings as it showed no increase in overall complication rate with TXA use. Clarification of the favorable side-effect profile of TXA combined with significant benefits has led to its rapid emergence as routine practice in TKA.

There are limitations to this study. The study design was retrospective and thus prone to selection bias. A very large sample size was included and baseline patient demographics were homogenous based on statistical comparison, which reduces this potential for partiality. Subanalysis of TXA use was confined to one group (TU), which lowers the sample size and limits the ability to draw conclusions, although this does reduce the confounding effect of tourniquet use. Further studies are needed to determine the combined effect tourniquet and TXA use. That this study was conducted at a single center among a specific demographic offers reliability and consistency; however, the results may be less applicable to the general population. A single surgeon was assigned to each treatment arm, which limits potential for performance bias. This study primarily focused on blood loss and immediate postsurgical outcomes with follow-up for 52-weeks. However, extended follow-up is necessary to further assess long-term effects of tourniquet use such as implant survival and prosthetic joint infections. Although not within the scope of this study, utilization of pain scores and other validated clinical outcome measures could provide a more all-encompassing assessment of the pros and cons of tourniquet use.

## Conclusions

In conclusion, our findings suggest that while operative times were longer with a greater postoperative drop in hemoglobin, TU TKA did not result in greater blood transfusion rates. Despite an increased operative time in the nontourniquet group, there was no significant difference in rate of wound infection, medical complications, or surgical complications. The use of TXA reduced the postoperative drop in hemoglobin, but had no effect on blood transfusion or complication rates, suggesting it can be used safely. Additional studies are indicated to further explore these findings.

## Conflict of interests

The final decision regarding this manuscript publication was made by an editor who does not have any relevant conflicts of interest. Editor in Chief, Greg Golladay, MD, recused himself from this manuscript.

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