



The Current Concept of Hemostasis in Total Knee Arthroplasty: A Narrative Review

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Maximizing hemostasis in total knee arthroplasty (TKA) remains a challenge today. Blood loss associated with knee joint reconstruction can lead to pain, joint stiffness, hemarthrosis, wound drainage, risk of infection, and slowed postoperative rehabilitation. This article reviews the current concept of hemostasis in TKA. The following topics are discussed in this article: (1) the types of blood loss in TKA, (2) the hemostatic effects of tranexamic acid (TXA) in TKA, (3) the advantages of the use of a tourniquet in TKA, (4) advantages and disadvantages of wound drainage after TKA, (5) benefits of cryotherapy in TKA and revision TKA, and (6) To compare the results of the use of TXA, platelet-rich plasma, and fibrin sealant in TKA.

Key words: Total knee arthroplasty, cryotherapy, hemostasis, tranexamic acid, tourniquet, blood loss

INTRODUCTION

According to our knowledge, adequate and maximize hemostasis in knee joint reconstruction remains a challenge. Up to 80% of patients undergoing total knee arthroplasty (TKA) have a metabolic comorbidity that may affect intraoperative hemostasis or postoperative tissue remodeling.^{1,2} The challenge is evident in multiple techniques used: tourniquets, hemostatic agents, hypotensive anesthesia, perioperative medications, various coagulation devices, reinfusion drains, and blood donation and transfusions. Blood loss is associated with complications with knee joint reconstruction such as pain, joint stiffness, hemarthrosis, wound drainage, risk of infection, and slowed postoperative rehabilitation, necessary to avoid blood transfusions, and associated costs and risks. Approximately 39% of cases require transfusions for blood loss.³ Adequate hemostasis has several benefits in TKA. Early mobilization can potentiate bleeding. Optional hemostasis in TKA is required for shortening hospital stay length and shortening outpatient care.

TYPES OF BLOOD LOSS IN TOTAL KNEE ARTHROPLASTY

Patient blood management has been defined as “the timely application of evidence-based medical and surgical concepts designed to maintain hemoglobin (Hb) concentration, optimize hemostasis, and minimize blood loss in an effort to improve patient outcome.”⁴ Blood loss can be categorized as measured blood loss (which can be quantified during operation), hidden blood loss (which cannot be quantified postoperation, such as hemarthrosis or soft tissue swelling), and total blood loss (the combination of measured and hidden blood loss). Park *et al.* conducted a study⁵ that enrolled 356 patients who underwent bipolar hemiarthroplasty with the diagnosis of femoral neck fracture and revealed the result: measured blood loss was 980 mL, and total blood loss was 1408 mL. Much more blood loss in patients with cardiovascular disease: 1526 mL. Highest blood loss in obese patients: 1605 mL. Sehat *et al.*⁶ also conducted another study that enrolled 101 cases of total

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hip arthroplasty (THA) and 101 cases of TKA. In the THA group: measured blood loss was 1038 mL, hidden blood loss was 471 mL (26%), and total blood loss was 1510 mL. In the TKA group: measured blood loss was 733 mL, hidden blood loss was 765 mL (49%), and total blood loss was 1496 mL [Table 1]. In this study, we realized hidden blood loss can be significant, especially in TKA.

IS BLOOD LOSS DECREASED BY UTILIZING TRANEXAMIC ACID?

Tranexamic acid (TXA) inhibits fibrinolysis as a clot stabilizer. It can be administered intravenously, topically, or orally. It attaches to the lysine site of plasminogen to prevent conversion to plasmin (plasmin degrades fibrin clots and fibrinogen).⁷ Good *et al.*⁸ conducted a prospective, randomized, and double-blinded study that calculated measured and hidden blood loss in study and control groups: the study group utilized 10 mg/kg TXA intravenous before the tourniquet was released, and another dose was given 3 h later; the control group was utilized placebo. The placebo group: measured blood loss was 845 mL, and hidden blood loss was 618 mL. The study group: measured blood loss was 385 mL, and hidden blood loss was 524 mL [Table 2]. This study revealed that antifibrinolytic agents (TXA) decreased total blood loss by 30% and measured blood loss by 50%. However, there was no difference in hidden blood loss.

As far as we know, utilizing a tourniquet in TKA decreases overall intraoperative blood loss, improves visualization, decreases the need for blood transfusion, improves the cement–bone interface, and may save surgery time. Despite the use of tourniquets in total knee arthroplasties being quite common, Abdel *et al.* published their survey of the American Association of Hip and knee surgeons,⁹ 100% of knee surgeons utilized a tourniquet in TKA in 2010, and it decreased to 88% in 2019.

Recent studies by Huang *et al.*¹⁰ and Rantasalo *et al.*¹¹ using TXA with or without a tourniquet in TKA decreased total blood loss without differences in transfusion rates. In the prospective randomized controlled trial by Huang *et al.*,¹⁰ they compared three groups: group A was treated with the tourniquet and TXA (IV TXA 5–10 min before skin incision (20 mg/kg) and 3, 6, 12, and 24 h after (10 mg/kg) along with 1 g topical TXA in 50 mL normal saline. The topical TKA was administered intraoperatively after component implantation by wound irrigation for 5–10 min, after which the solution was aspirated), Group B was treated with TXA only, and Group C was treated with a tourniquet only. Furthermore, the result was no difference between Groups A and B in terms of total blood loss, drainage volume, intraoperative blood loss, blood

transfusion rate, or maximum change in Hb. Wound drainage was much higher in the tourniquet groups.

Rantasalo *et al.* published their level 1 study which found the different outcomes after TKA between four study groups: spinal anesthesia with tourniquet, spinal anesthesia without tourniquet, general anesthesia with tourniquet, and general anesthesia without tourniquet.¹¹ At a 90-day follow-up, the tourniquet had no adverse effect on TKA outcomes (Oxford Knee Score, complications, and readmission rate). However, the tourniquet group was more likely than the nontourniquet group to pass the Oxford Knee Score at the 1-year follow-up.

EFFECT OF TOURNIQUET IN TOTAL KNEE ARTHROPLASTY

Pavão *et al.* conducted a comparative, prospective, and randomized study to determine the efficacy of TNQs in primary TKA. This study evaluated 127 patients aged 55–85 years who had severe knee arthritis and were undergoing primary TKA. Both groups received 1 g of TXA intravenously before induction of anesthesia. An additional 750 mg diluted in 15 mL of saline was applied to the surgical wound after cement drying. Postoperative blood loss at 24 h was 630 versus 670 mL (TNQ vs. no TNQ, $P = 0.59$) and at 72 h was 930 versus 950 mL (TNQ vs. no TNQ, $P = 0.96$) [Table 3].¹²

To analyze the effect of TNQ, Hoffmann *et al.* performed a prospective cohort study of 511 primary TKA with a 5-year follow-up. Superficial surgical site infection was 1% versus 0.9% (TNQ vs. no TNQ). Deep surgical site infection was 0.7% versus 1.7% (TNQ vs. no TNQ). The reoperation rate was 4.3% in both groups.¹³

A retrospective cohort study of 1212 patients undergoing aseptic revision TKA (rTKA) was conducted by Singh *et al.* The indications for aseptic rTKA were: mechanical loosening, instability, arthrofibrosis, periprosthetic fracture, hardware failure, pathology of the extensor mechanism, and all other aseptic reasons including ankylosis, contracture, pain, synovitis, thrombosis, and osteolysis. Blood loss was 224 mL versus 325 mL (TNQ vs. no TNQ, $P < 0.001$). In a subgroup analysis of 333 patients who underwent isolated polyethylene liner replacement, blood loss was 211 mL versus 288 mL (TNQ vs. no TNQ, $P = 0.037$). In 879 patients who underwent component replacement, blood loss was 229 mL versus 344 mL (TNQ vs. no TNQ, $P < 0.001$) [Table 4].¹⁴

A prospective, double-blind, and randomized controlled trial on the effect of tourniquet in robotic-assisted TKA was conducted by Lai *et al.* A total of 28 patients were randomly scheduled for robotic TKA. All patients received 2 g of intravenous TXA 30 min before the incision and 1 g of intravenous TXA at 3 h and 6 h after the operation. Before

Table 1: Blood loss in Sehat *et al.* study^[6]

Surgery type	Measured blood loss (mL)	Hidden blood loss (mL)	Total blood loss (mL)
THA	1038	471	1510
TKA	733	765	1496

THA=Total hip arthroplasty, TKA=Total knee arthroplasty

Table 2: Blood loss in Good *et al.* study^[8]

Intervention	Measured blood loss (mL)	Hidden blood loss (mL)
TXA (10 mg/kg) IV before TNQ release and repeated after 3 h	385	524
Placebo	845	618

TKA=Total knee arthroplasty, IV=Intravenous

Table 3: Blood loss in Pavão *et al.* study^[12]

Intervention	24-h postoperative blood loss (mL)	72-h postoperative blood loss (mL)
To utilize a TNQ in primary TKA	630	930
No TNQ	670	950

TKA=Total knee arthroplasty

Table 4: Blood loss in Singh *et al.* study^[14]

Intervention	Blood loss (mL)	<i>P</i>
All patient	224	<0.001
All patient (no TNQ)	325	
Isolated liner replacement	211	0.037
Isolated liner replacement (no TNQ)	288	
Component replacement	229	<0.001
Component replacement (no TNQ)	344	

Table 5: Blood loss in Lai *et al.* study^[15]

Intervention	Intraoperative blood loss (mL)	Hidden blood loss (mL)
To utilize TNQ in robotic-assisted TKA	134	511
No TNQ	308	366

TKA=Total knee arthroplasty

Table 6: The data in Morsi study^[17]

	Cold flow group	Control group
ROM at the 1 st week (°)	48–87	25–63
Drainage volume of Hemovac (mL)	503	810
VAS	4.2	6.3
Analgesic consumption (mg)	950	1400

VAS=Visual Analog Pain Score, ROM=Range of motion

TXA, all patients received 5 mg intravenous dexamethasone. The tourniquet group showed significantly lower intraoperative

blood loss (134 vs. 308 mL, $P < 0.001$), but significantly higher hidden blood loss (511 vs. 366 mL, $P = 0.002$) [Table 5].¹⁵

THE USE OF WOUND DRAIN?

The efficacy of surgical wound drainage after TKA remains debated. However, we know drainage after TKA can decompress the hematoma and reduce tension and pressure in the soft tissues, thereby reducing wound leakage and complications. Maliarov *et al.*¹⁶ conducted a randomized control study to evaluate the impact of drainage on early outcomes postoperatively. No significant differences between utilizing drainage or not in terms of blood loss, hospital stay length, range of motion (ROM) of the knee joint, and clinical score (knee injury and osteoarthritis outcome score). Disadvantages of the drainage method include increased cost of operation, a potential for contamination, and increased complications for further treatment.

CRYOTHERAPY AFTER TOTAL KNEE ARTHROPLASTY AND REVISION TOTAL KNEE ARTHROPLASTY

The use of cryotherapy (or cold therapy) after TKA remains controversial. Some studies have suggested the potential benefits of cryotherapy in minimizing blood loss after TKA. Morsi conducted a prospective study that enrolled 60 patients using continuous flow cryotherapy after TKA.¹⁷ The result was better in the cryotherapy group in terms of ROM of the knee joint (cold flow group = 48° to 87° vs. control group = 25° to 63°, $P < 0.1$ at the 1st week after surgery, and at 2 weeks, 80% of Group 1 and 64% of Group 2 had achieved 90° of flexion), the volume of Hemovac output (the mean drainage volume of the cold flow group was 503 mL and the control group was 810 mL, $P < 0.001$), postoperative pain (the mean visual analog score (VAS) of the cold flow group was 4.2 and that of the control group was 6.3 during the 6-day postoperative period), and analgesia consumption (the mean analgesia consumption for the cold flow group was 1.9 tablets [950 mg] and for the control group was 2.8 tablets [1400 mg], $P < 0.01$) [Table 6].

Ruffilli *et al.* designed a prospective, randomized controlled trial that compared the difference between cryotherapy and a traditional icing regimen.¹⁸ The cryotherapy group did not show better outcomes in terms of soft-tissue swelling, postoperative pain, and blood loss in the acute postoperative settings. Due to the costs, it should be reserved for selected cases.

Murgier *et al.* conducted a prospective case-control study (level of evidence: 1) to compare the difference between cryotherapy with dynamic intermittent compression (CDIC) and the traditional method of the cold pack only.¹⁹ The total

Table 7: The data in Murgier *et al.* study^[19]

	CDIC group	Control group
Total blood loss (mL)	260	460
VAS on postoperative day 3	1	3

CDIC=Cryotherapy with dynamic intermittent compression, VAS=Visual Analog Pain Score

blood loss was lower in the CDIC group than in the control group (260 mL vs. 460 mL; $P < 0.05$). Pain at rest on postoperative day 3 was lower in the CDIC group (VAS 1 vs. 3; $P < 0.05$) [Table 7]. CDIC lowers postoperative blood loss and decreases pain in the acute setting of rTKA.

OTHER HEMOSTATIC AGENTS IN TOTAL KNEE ARTHROPLASTY

Li *et al.* conducted a meta-analysis of 37 randomized controlled trials with 3972 patients.²⁰ They compared the difference between four groups: placebo or sham treatment, platelet-rich plasma (PRP), TXA (more than 1.5 g or <1.5 g) plus diluted epinephrine, and a high or low dose of fibrin sealant (more than 5 mL or <5 mL). Topical administration of TXA + diluted epinephrine, fibrin sealant, and TXA (>1.5 g and <1.5 g) can significantly reduce total blood loss and Hb drop in TKA compared with placebo, suggesting that TXA plus diluted epinephrine may be the most likely optional topical hemostatic agent with higher efficacy and safety. This may be by significantly reducing total blood loss and Hb drop and decreasing the blood transfusion rate in TKA.

CONCLUSION

For hemostasis in total joint arthroplasty, TXA is used almost universally and is effective in stopping bleeding. Compared with PRP and fibrin sealant, TXA (>1.5 g or <1.5 g) with diluted epinephrine has the better results for hemostasis. TXA is significantly more effective than a tourniquet in reducing blood loss in TKA. There are no supporting data for other topical agents (PRP and fibrin sealant). Tourniquets have been shown to be effective in controlling bleeding in rTKA and robotic-assisted TKA. However, tourniquets used in primary TKA were not as effective in stopping bleeding. Sealing properties may be more appropriate for early mobilization. CDIC may be beneficial in rTKA, although there is no evidence for cryotherapy in primary TKA. Patients who recover faster and are discharged earlier may benefit from adequate hemostasis.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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Conflicts of interest

There are no conflicts of interest.

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