DOI: 10.37990/medr.1554458 Med Records 2025;7(1):43-9

MEDICAL RECORDS-International Medical Journal

Research Article

Comparison of Tourniquet and Non-Tourniquet Use in Total Knee Arthroplasty: Impact on Postoperative Hemoglobin Changes and Surgical Time

Cumhur Deniz Davulcu, Muhammed Yusuf Afacan

İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, Department of Orthopaedics and Traumatology, İstanbul, Türkiye

Abstract

Aim: This study aimed to evaluate the impact of pneumatic tourniquet use on postoperative hemoglobin (Hb) and hematocrit (Hct) levels, changes in Hb/Hct, and surgery duration in total knee arthroplasty (TKA) by comparing outcomes between patients who underwent the procedure with and without tourniquet application.

Material and Method: A retrospective cohort study was conducted on 130 patients with Kellgren-Lawrence grade 3-4 gonarthrosis who underwent TKA. Patients were divided into two groups, each with 65 patients, based on tourniquet use. Preoperative and postoperative day 1 Hb/Hct values, ΔHb/ΔHct, and surgery duration were compared. Patients with comorbidities and significant perioperative complications were excluded.

Results: No significant differences were found between the tourniquet and non-tourniquet groups for preoperative or postoperative Hb and Hct levels ($p>0.05$). Both groups experienced significant reductions in hemoglobin and hematocrit levels postoperatively. The non-tourniquet group had a slightly greater decrease in hemoglobin and hematocrit, although this difference was not statistically significant ($p>0.05$). The tourniquet group demonstrated a significantly shorter operation duration ($p=0.004$).

Conclusion: Tourniquet use in TKA reduces surgical time without significantly affecting blood loss. The comparable outcomes in both groups suggest that the use of a tourniquet may offer practical advantages, in terms of procedural efficiency in reducing surgical time, but its influence on postoperative Hb and Hct changes is minimal.

Keywords: Total knee arthroplasty, tourniquet use, hemoglobin change, hematocrit change, blood loss, surgical time

INTRODUCTION

Total knee arthroplasty (TKA) is widely regarded as the most successful intervention for alleviating pain, correcting deformities, and improving mobility in severe knee osteoarthritis, making it one of the most frequently performed orthopedic procedures globally (1-3). However, it is not without complications, including significant blood loss (3,4), periprosthetic joint infection (5,6), and periprosthetic fractures (7).

Various methods have been developed to address the complication of blood loss, including the use of pneumatic tourniquets and suction drains, advancements in surgical techniques, the administration of tranexamic acid, and local infusion with norepinephrine, among others (3,8). The tourniquet is a commonly employed method to address these complications to achieve hemostasis in clinical practice, demonstrating high efficacy in minimizing intraoperative bleeding. Beyond reducing blood loss, it also aids in maintaining a clear and unobstructed surgical field (2,9). However, it is also not without complications, including skin abrasions and blistering, wound hematomas, wound oozing and healing problems, muscle injury, rhabdomyolysis, nerve palsy,

CITATION
Davulcu CD, Afacan MY. Comparison of Tourniquet and Non-Tourniquet Use in Total Knee Arthroplasty: Impact on Postoperative Hemoglobin Changes and Surgical Time. Med Records. 2025;7(1):43-9. DOI:1037990/medr.1554458

Received: 22.09.2024 **Accepted:** 19.10.2024 **Published:** 25.12.2024
Corresponding Author: Cumhur Deniz Davulcu, İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, Department of Orthopaedics and Traumatology, İstanbul, Türkiye
E-mail: cumhurdeniz.davulcu@iuc.edu.tr

postoperative stiffness and pain, deep vein thrombosis (DVT), pulmonary embolism (PE), and infections (4,10,11).

Despite this, meta-analysis results in the literature also indicate that while the use of a tourniquet reduces intraoperative bleeding, it may increase the total blood loss postoperatively (4,12,13). We hypothesized that the use of a tourniquet during TKA would result in a comparable decrease in hemoglobin (Hb) and hematocrit (Hct) levels postoperatively, while also shortening the operation duration compared to surgeries performed without a tourniquet. Therefore, performing the surgery without a tourniquet may not only provide similar blood loss outcomes but also avoid the potential complications associated with tourniquet use. This study aims to assess the impact of tourniquet use on postoperative Hb and Hct levels, the changes in Hb/Hct from pre- to postoperative periods, and the duration of the surgical procedure in TKA, by comparing outcomes between patients with and without tourniquet application.

MATERIAL AND METHOD

Within this retrospective cohort study, a total of 130 patients who underwent TKA were included in the analysis. These patients were divided into two groups depending on whether a tourniquet was used during their procedure: one group had tourniquets applied, while the other did not. In the study, patients with Kellgren-Lawrence grade 3-4 gonarthrosis who underwent TKA, with no known hematologic disorders, preoperative Hb and Hct levels above 10/30, and no significant abnormalities in preoperative complete blood count were randomly included. Patients with cruciate-retaining prostheses were included in the study. This ensured that prosthesis selection did not introduce any confounding factors that could affect the study outcomes. The use of a tourniquet was random, and the surgeons were experienced in performing the surgery both with and without a tourniquet. Patients for whom preoperative and postoperative day 1 Hb/Hct values and surgery duration were accessible through the hospital system were included in the study. Patients with a history of tumors or tumor surgery, a history of infections, rheumatological conditions (to avoid bleeding complications related to vasculitis), those on regular corticosteroid therapy, patients with diabetes mellitus, morbid obesity, those who had undergone previous surgery in the same area, and those with known renal, hepatic, cerebrovascular, cardiovascular, peripheral vascular diseases, chronic obstructive pulmonary disease (COPD), hyperlipidemia, a history of thromboembolic events, anemia, or coagulation disorders, patients who required blood transfusions during surgery or experienced substantial blood loss (more than 500 mL) during the procedure, cases with incomplete medical records or missing postoperative Hb and Hct data were excluded from the study. Demographic data, including age, sex, and relevant medical history, were obtained from patient records. Hb and Hct levels were measured preoperatively, within 24 hours before surgery, and postoperatively, within 24 hours after surgery. Additional surgical information, such as whether a tourniquet was used and the length of the operation, was also recorded. Changes in hemoglobin (ΔHb) and hematocrit (ΔHct) were calculated by subtracting the postoperative values from the preoperative values for each patient. All patient data were anonymized to maintain confidentiality.

Before the incision, the tourniquets placed around the proximal thigh were inflated to 250-300 mmHg, depending on the patient's mean arterial pressure. The surgical procedure utilized a medial parapatellar approach, with patellar eversion and lateral dislocation. The menisci and anterior cruciate ligament were excised, and cruciate-retaining prostheses were implanted. Standard knee arthroplasty techniques were employed for the femoral and tibial cuts, with an intramedullary guide for the femoral cuts and an extramedullary guide for the tibial cuts. All prostheses were cemented in place. Postoperatively, patients were monitored in the ward, where follow-up hematologic tests were performed, and thromboembolism prophylaxis was administered.

The study protocol was approved by the İstanbul University-Cerrahpaşa Rectorate Clinical Research Ethics Committee under protocol number E-83045809-604.01-1058935 on August 7, 2024, and all procedures were conducted in compliance with good clinical practice and the principles of the Declaration of Helsinki.

Statistical Methods

In the context of this study, the sample size was determined through the power analysis. Using G*Power (Version 3.1.9.6), the analysis indicated a 95% confidence level, an effect size of 0.50, and a power value of 0.80. Based on these parameters, the minimum required sample size was calculated to be 126 participants, with at least 63 individuals in each group. For the analysis and statistical evaluation of the data, IBM SPSS Statistics version 26.0 was utilized, with a 95% confidence level. To determine whether the measurements followed a normal distribution, skewness and kurtosis coefficients were examined. Skewness and kurtosis values between +3 and -3 are considered indicative of a normal distribution (14). Since the skewness and kurtosis values derived from the measurements fell within the range of +3 to -3, the assumption of normality was met, allowing the use of parametric test techniques in our analyses (Table 1). The difference in measurements based on tourniquet use was analyzed using an independent samples t-test. The relationship between tourniquet uses and age was examined using a Chi-square test. Pre- and post-intervention changes with respect to tourniquet use were analyzed using a paired samples t-test.

Table 1. Since the skewness and kurtosis values obtained from the variables fall within the range of +3 to -3, the assumption of normality has been satisfied

Normality test	n	Skewness	Kurtosis
Age	130	0.011	0.809
Preoperative Hb	130	0.321	-0.474
Postoperative Hb	130	0.494	-0.468
Delta Hb	130	1.065	2.022
Preoperative Hct	130	0.218	0.366
Postoperative Hct	130	0.446	-0.264
Delta Hct	130	0.684	1.590
Operation duration	130	0.035	-1.449

RESULTS

In the group where a tourniquet was used, 80% were female and 20% were male, while in the group without tourniquet use, 75.4% were female and 24.6% were male. Overall, females accounted for 77.7%, and males made up 22.3% of the total sample. The Chi-square test revealed no significant relationship between gender and tourniquet use (p=0.674) (Table 2). The mean age in the group using a tourniquet was 65.51±8.67, while in the group without tourniquet use, the mean age was 64.86±8.17. The overall mean age was 65.18±8.39. The t-test showed no significant difference between age and tourniquet use (p=0.663) (Table 2).

Table 2. Analysis of gender and age in relation to tourniquet use

		Tourniquet use			p
		+	-	Total	
		n (%)	n (%)	n (%)	
*Gender	Female	52 (80)	49 (75.4)	101 (77.7)	0.674
	Male	13 (20)	16 (24.6)	29 (22.3)	
**Age (mean±SD)		65.51±8.67	64.86±8.17	65.18±8.39	0.663

*Chi-Square Test, **t-Test

The mean preoperative Hb in the group using a tourniquet was 12.86±1.31, while it was 12.84±1.33 in the group not using a tourniquet. The t-test results indicated no significant difference between tourniquet use and preoperative Hb (p=0.926). The mean postoperative Hb was 11.46±1.51 in the tourniquet group, compared to 11.09±1.45 in the non-tourniquet group. The t-test revealed no significant difference between tourniquet use and postoperative Hb (p=0.151). The mean DELTA Hb was 1.4±0.85 in the tourniquet group, while it was 1.75±1.53 in the non-tourniquet group. The t-test showed no significant difference between tourniquet use and DELTA Hb (p=0.107). The mean preoperative Hct was 37.76±3.9 in the tourniquet group, compared to 37.75±3.66 in the non-tourniquet group. The t-test indicated no significant difference between tourniquet use and preoperative Hct (p=0.987) (Table 3).

Table 3. Analysis of measurements in terms of tourniquet use

	Tourniquet use			p
	+	-	Total	
	mean±SD	mean±SD	mean±SD	
Preoperative Hb	12.86±1.31	12.84±1.33	12.85±1.31	0.926
Postoperative Hb	11.46±1.51	11.09±1.45	11.28±1.49	0.151
Delta Hb	1.4±0.85	1.75±1.53	1.57±1.25	0.107
Preoperative Hct	37.76±3.9	37.75±3.66	37.76±3.77	0.987
Postoperative Hct	33.89±4.33	33.17±4.22	33.53±4.28	0.340
Delta Hct	3.87±3.07	4.58±4.29	4.23±3.73	0.282
Operation duration	36.15±5.64	39.08±5.58	37.62±5.78	**0.004**

Independent t-Test

The mean postoperative Hct was 33.89±4.33 in the tourniquet group and 33.17±4.22 in the non-tourniquet group. The t-test found no significant difference between tourniquet use and postoperative Hct (p=0.340). The mean DELTA Hct was 3.87±3.07 in the tourniquet group, compared to 4.58±4.29 in the non-tourniquet group. The t-test showed no significant difference between tourniquet use and DELTA Hct (p=0.282). The mean operation duration was significantly shorter in the tourniquet group (36.15±5.64 minutes) compared to the non-tourniquet group (39.08±5.58 minutes). The t-test results indicated a significant difference between tourniquet use and operation duration (p=0.004) (Table 3).

In patients where a tourniquet was used, the average preoperative Hb level decreased from 12.86±1.31 to 11.46±1.51 postoperatively. This reduction was statistically significant according to the paired samples t-test (p=0.0001), with a decrease of 1.4 g/dL in Hb levels observed in this group. In patients where no tourniquet was used, the average preoperative Hb level dropped from 12.84±1.33 to 11.09±1.45 postoperatively. This difference was also statistically significant according to the paired samples t-test (p=0.0001), with a 1.75 g/dL decrease in Hb levels noted in the non-tourniquet group. In the tourniquet group, the average preoperative Hct level decreased from 37.76±3.9 to 33.89±4.33 postoperatively. This reduction was found to be statistically significant by the paired samples t-test (p=0.0001), with a 3.87 unit decrease in Hct levels. In the non-tourniquet group, the average preoperative Hct level fell from 37.75±3.66 to 33.17±4.22 postoperatively. This change was also statistically significant according to the paired samples t-test (p=0.0001), with a 4.58 unit decrease in Hct levels observed (Table 4).

Table 4. Analysis of preoperative, and postoperative changes in hb and hct values based on tourniquet use

	Tourniquet use					
	+			-		
	Pre	Post	p	Pre	Post	p
	mean±SD	mean±SD		mean±SD	mean±SD	
Hb	12.86±1.31	11.46±1.51	**0.0001**	12.84±1.33	11.09±1.45	**0.0001**
Hct	37.76±3.9	33.89±4.33	**0.0001**	37.75±3.66	33.17±4.22	**0.0001**

The paired samples t-test

The reduction in Hb was greater in the non-tourniquet group (1.75 g/dL) compared to the tourniquet group (1.4 g/dL). Similarly, the decrease in Hct was more pronounced in the non-tourniquet group (4.58 units) compared to the tourniquet group (3.87 units) (Table 3). Although both groups experienced significant reductions in Hb and Hct levels, the decreases were slightly more substantial in the non-tourniquet group (Figures 1,2).

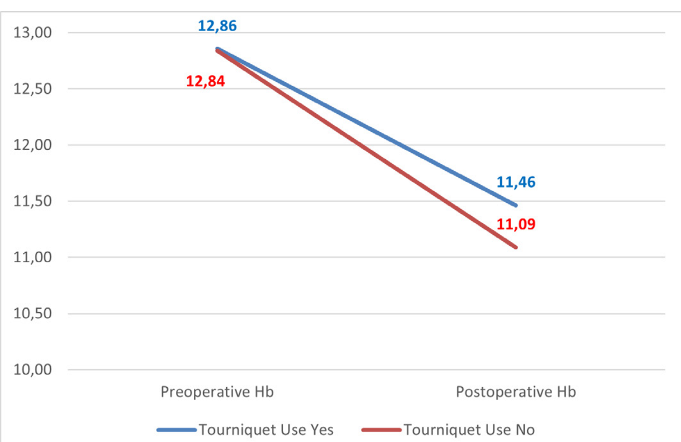

Figure 1. Preoperative and postoperative Hb levels in patients undergoing TKA with or without tourniquet use; the blue line represents patients where a tourniquet was used, and the red line represents patients where a tourniquet was not used; both groups show a decrease in Hb levels postoperatively, with slightly less reduction in the tourniquet group

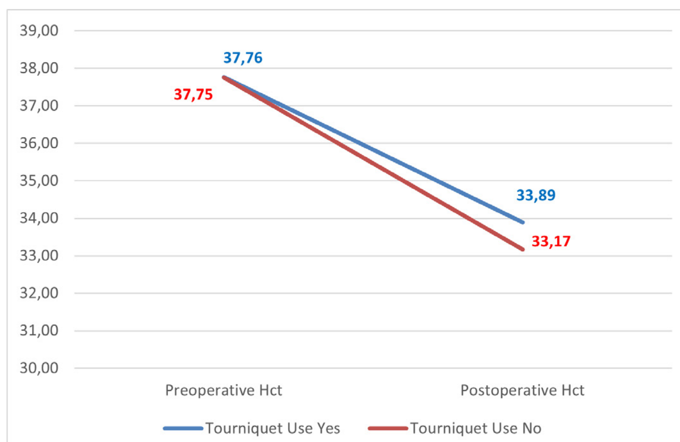

Figure 2. Preoperative and postoperative Hct levels in patients undergoing TKA with or without tourniquet use; the blue line represents patients where a tourniquet was used, and the red line represents patients where a tourniquet was not used; both groups show a decrease in Hct levels postoperatively, with the tourniquet group demonstrating a marginally smaller reduction

DISCUSSION

TKA remains one of the most effective treatments for severe osteoarthritis, but the role of tourniquet use continues to be debated due to its potential benefits and risks. In this study, we aimed to evaluate the impact of tourniquet use on postoperative Hb and Hct levels, as well as surgical time. The main findings of this study revealed that both tourniquet and non-tourniquet groups experienced significant reductions in Hb and Hct levels postoperatively. However, the decrease in both Hb and Hct was slightly greater in the non-tourniquet group compared to the tourniquet group, though the difference was not statistically significant. Additionally, the operation duration was significantly shorter in the tourniquet group. These findings suggest that while the use of a tourniquet may reduce surgical time, its effect on blood loss is comparable to non-tourniquet use. The use of a tourniquet has traditionally been recommended to minimize blood loss. However, numerous studies have compared TKA procedures performed with and without a tourniquet, and the findings remain inconclusive (15). These results align with the ongoing debate in the literature regarding the benefits and drawbacks of tourniquet use in TKA.

Albayrak et al. found that while tourniquet use in TKA may not significantly reduce blood loss and can cause temporary extremity pain, it is beneficial for patients without comorbidities. Tourniquet use creates a bloodless environment during cementing, improving prosthesis longevity and potentially avoiding revision surgeries. The study recommends using tourniquets in patients without comorbidities, provided these are clearly documented before surgery (2). In our study, we included only patients without comorbidities in both groups, thus eliminating the potential effects of comorbidities on the outcomes. In both groups, similar Hb/Hct reductions were observed, as found in this study.

The literature reveals a range of outcomes regarding tourniquet application in TKA. Arthur et al.'s review also showed that several studies have examined the effectiveness of limited-use tourniquets, with mixed outcomes (15). Ishii and Matsuda's prospective randomized controlled trial (RCT) found that releasing the tourniquet before wound closure resulted in significantly higher total blood loss compared to releasing it after closure, though no significant difference in transfusion rates was noted between the two groups. Furthermore, Ishii and Matsuda, in another RCT, evaluated the impact of different tourniquet pressures, finding no significant differences in blood loss or transfusion requirements when comparing higher and lower tourniquet pressures (16,17). Similarly, Huang et al. conducted a systematic review and meta-analysis, concluding that early tourniquet release led to higher intraoperative blood loss (18). On the other hand, Rama et al. found that while total blood loss was higher in the early release group, the late release group experienced significantly more complications requiring return to the operating room (19). Contrary to these findings, Schnettler et al. observed a paradoxical increase in total blood loss with the use of a limited tourniquet. Their retrospective cohort study demonstrated that using a tourniquet during cementation resulted in greater blood loss compared to the use of tranexamic acid (TXA) alone. The authors proposed that tourniquet use restricted the delivery of TXA to tissues, leading to hidden blood loss (20). In the light of his literature review Arthur et al. prefer using a tourniquet inflated to 300 mm Hg until cementing is complete, followed by deflation. Before deflation, they inject a periarticular analgesic mixture containing ropivacaine, epinephrine, morphine, and ketorolac. They also administer 1,000 mg of TXA before inflation and another 1,000 mg after deflation. Tourniquet time is limited to 120 minutes, with adjustments made for longer surgeries or patients with vascular conditions. In cases of peripheral arterial bypass grafts, the tourniquet is avoided entirely (15).

Conversely, Zhang et al. conclude that TKA without a tourniquet is superior in reducing thromboembolic events and related complications, without significant differences in actual blood loss between groups. They also suggest that using a tourniquet may hinder early postoperative rehabilitation exercises (10). Tirumala et al. found that while omitting the tourniquet in revision TKA increased perioperative blood loss, it did not significantly affect transfusion rates. Additionally, patients who underwent revision TKA without a tourniquet experienced shorter postoperative hospital stays, fewer 30-day readmissions, and improved range of flexion (21). In the metaanalysis of Cai et al., the authors concluded that using a tourniquet in TKA significantly reduces intraoperative blood loss, calculated blood loss, and operation time, but it does not have a notable impact on reducing the rate of transfusion or DVT (22). Similarly, Yi et al. suggested that while tourniquet use can reduce surgical time, intraoperative, and total blood loss, it also leads to an increase in postoperative total blood loss. Additionally, they observed a higher incidence of postoperative complications such as DVT and surgical site infections in the tourniquet group (12). Other studies, like those by Zak et al., suggested that while tourniquet use does not influence the average cement penetration depth, it increases the chances of achieving optimal cement penetration during the procedure (23).

In terms of recovery and complications, Huang et al. concluded that tourniquet use during TKA significantly increases total blood loss without reducing postoperative transfusion rates. Furthermore, it worsens early postoperative hypercoagulable conditions and leads to a higher incidence of asymptomatic below-knee DVT, as detected by conventional coagulation tests, thromboelastography, and ultrasonic Doppler (24). In contrast, Pavao et al. found that using an optimized tourniquet in primary TKA resulted in clinical outcomes similar to surgery without a tourniquet and did not raise the risk of postoperative complications. The tourniquet provided the advantage of a clean and dry surgical field without increasing procedure-related comorbidities (25). However, Johnsen et al. concluded that tourniquet use significantly alters angiogenic gene expression, which may contribute to postoperative interstitial edema, increased pain, and decreased muscle strength. These factors could delay rehabilitation and ultimately reduce patient satisfaction after TKA. (26). Xie et al. also concluded that the meta-analysis results indicate tourniquet application may increase the incidence of postoperative DVT and worsen postoperative pain and swelling in the short term (27).

On top of these, Nicolaiciuc et al. concluded that there was no significant correlation between tourniquet use and postoperative pain or range of motion (ROM) improvement (28). Smith et al. found in their systematic review no benefit to using a tourniquet in knee replacement surgery for reducing transfusion requirements (29). Tan et al. concluded that tourniquet use in TKA does not shorten surgery time or reduce blood loss, but it does lead to an increase in local complications (4). Joufflineau et al. concluded that using a low-pressure tourniquet in TKA reduces total blood loss compared to no tourniquet, without significantly increasing hidden blood loss and does not exhibit superior functional outcomes (30). Zan et al. concluded that releasing the tourniquet before wound closure increases perioperative blood loss but significantly reduces the risk of complications (31). Kim et al. stated that inflating the tourniquet to 120 mmHg above systolic blood pressure (SBP) is an effective method for use during TKA (32). Hung et al. concluded that performing TKA without a tourniquet preserves better quadriceps muscle function, leading to faster recovery and reduced need for transfusions, while also avoiding tourniquet-related complications (33). Xu et al. found that the use of a tourniquet in routine primary TKA was associated with a higher transfusion rate and a longer postoperative length of stay (PLOS) (34). Andrade et al. concluded that there were no significant differences in functional outcomes or cementation quality between two different tourniquet protocols in TKA. Whether the tourniquet was used throughout the entire procedure or only during skin incision and cementation, no differences were observed in visual pain scale (VAS), Oxford knee scores, range of motion, or radiolucent line analysis. Thus, both techniques appeared to provide similar clinical outcomes (35).

Limitations

This study was conducted at a single institution, which may introduce bias related to the specific surgical techniques, postoperative care protocols, and patient demographics of that center, potentially limiting the generalizability of the findings. Additionally, while the study focused on Hb and Hct changes, it did not assess other important postoperative outcomes such as pain, functional recovery, DVT, or wound complications, which are critical when evaluating tourniquet use. The non-blinded design may have further introduced performance or response bias, potentially influencing subjective outcomes like pain scores and rehabilitation progress. Future studies should incorporate a more comprehensive evaluation of these outcomes to provide a holistic view of the effects of tourniquet application in TKA.

CONCLUSION

This study provides valuable insights into the impact of tourniquet use on Hb, Hct levels, and surgical time in TKA. While both tourniquet and non-tourniquet groups experienced similar reductions in these parameters, tourniquet use resulted in shorter operative times without significantly affecting blood loss. Although the study did not explore postoperative complications like thromboembolic events and delayed rehabilitation, the literature suggests that tourniquet use may be associated with such risks. Future research should address these limitations by incorporating a broader evaluation of functional outcomes and complications to better guide clinical decision-making in TKA.

Financial disclosures: *The authors declared that this study has received no financial support.*

Conflict of interest: *The authors have no conflicts of interest to declare.*

Ethical approval: *This study was approved by the İstanbul University-Cerrahpaşa Rectorate Clinical Research Ethics Committee.*

REFERENCES

1. Zhang HC, Zhang Y, Dai HB, et al. Preoperative anemia and complications after total joint arthroplasty: a systematic review and meta-analysis. Eur Rev Med Pharmacol Sci. 2022;26:7420-30.
2. Albayrak M, Ugur F. With or without a Tourniquet? a comparative study on total knee replacement surgery in patients without comorbidities. Medicina (Kaunas). 2023;59:1196.
3. Barros MFFH, Ribeiro EJC, Dias RG. Blood level changes in total knee arthroplasty with and without a tourniquet. Rev Bras Ortop. 2017;52:725-30.
4. Tan Y, Guo S, Wang H, et al. The effects of tourniquet use on blood loss and perioperative complications in total knee arthroplasty. BMC Musculoskelet Disord. 2023;24:847.
5. Afacan MY, Davulcu CD, Kaynak G, et al. A rare case of periprosthetic joint infection with streptococcus dysgalactiae subspecies dysgalactiae. Indian J Orthop. 2024;58:606-12.
6. Parvizi J, Tan TL, Goswami K, et al. The 2018 definition of periprosthetic hip and knee infection: an evidence-based and validated criteria. J Arthroplasty. 2018;33:1309-14.e2.
7. Aebischer AS, Hau R, de Steiger RN, et al. Distal femoral replacement for periprosthetic fractures after TKA: Australian Orthopaedic Association national joint replacement registry review. J Arthroplasty. 2022;37:1354-8.
8. Richardson MK, Liu KC, Mayfield CK, et al. Tranexamic acid is safe in patients with a history of venous thromboembolism undergoing total joint arthroplasty. J Bone Joint Surg Am. 2024;106:30-8.
9. Tai TW, Chang CW, Lai KA, et al. Effects of tourniquet use on blood loss and soft-tissue damage in total knee arthroplasty: a randomized controlled trial. J Bone Joint Surg Am. 2012;94:2209-15.

10. Zhang W, Li N, Chen S, et al. The effects of a tourniquet used in total knee arthroplasty: a meta-analysis. J Orthop Surg Res. 2014;9:13.

11. Olivecrona C, Lapidus LJ, Benson L, Blomfeldt R. Tourniquet time affects postoperative complications after knee arthroplasty. Int Orthop. 2013;37:827-32.

12. Yi S, Tan J, Chen C, et al. The use of pneumatic tourniquet in total knee arthroplasty: a meta-analysis. Arch Orthop Trauma Surg. 2014;134:1469-76.

13. Jiang FZ, Zhong HM, Hong YC, Zhao GF. Use of a tourniquet in total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. J Orthop Sci. 2015;20:110-23.

14. Groeneveld RA, Meeden G. Measuring Skewness and Kurtosis. The Statistician. 1984;33:391.

15. Arthur JR, Spangehl MJ. Tourniquet use in total knee arthroplasty. J Knee Surg. 2019;32:719-29.

16. Ishii Y, Matsuda Y. Effect of the timing of tourniquet release on perioperative blood loss associated with cementless total knee arthroplasty: a prospective randomized study. J Arthroplasty. 2005;20:977-83.

17. Ishii Y, Matsuda Y. Effect of tourniquet pressure on perioperative blood loss associated with cementless total knee arthroplasty: a prospective, randomized study. J Arthroplasty. 2005;20:325-30.

18. Huang Z, Ma J, Zhu Y, et al. Timing of tourniquet release in total knee arthroplasty. Orthopedics. 2015;38:445-51.

19. Rama KRBS, Apsingi S, Poovali S, Jetti A. Timing of tourniquet release in knee arthroplasty. J Bone Jt Surg. 2007;89:699-705.

20. Schnettler T, Papillon N, Rees H. Use of a tourniquet in total knee arthroplasty causes a paradoxical increase in total blood loss. J Bone Joint Surg Am. 2017;99:1331-6.

21. Tirumala V, Klemt C, Oganseyan R, et al. Outcomes of tourniquet-less revision total knee arthroplasty: a matched cohort analysis. J Am Acad Orthop Surg. 2021;29:e1343-52.

22. Cai DF, Fan QH, Zhong HH, et al. The effects of tourniquet use on blood loss in primary total knee arthroplasty for patients with osteoarthritis: a meta-analysis. J Orthop Surg Res. 2019;14:348.

23. Zak SG, Tang A, Pivec R, et al. The effects of tourniquet on cement penetration in total knee arthroplasty. Arch Orthop Trauma Surg. 2023;143:2877-84.

24. Huang CR, Pan S, Li Z, et al. Tourniquet use in primary total knee arthroplasty is associated with a hypercoagulable status: a prospective thromboelastography trial. Int Orthop. 2021;45:3091-100.

25. Pavão DM, Pires eAlbuquerque RS, de Faria JLR, et al. Optimized tourniquet use in primary total knee arthroplasty: a comparative, prospective, and randomized study. J Arthroplasty. 2023;38:685-90.

26. Johnsen M, Mousavizadeh R, Scott A, et al. The tourniquet's effects on skeletal muscle during total knee arthroplasty. J Orthop Res. 2024;42:1955-63.

27. Xie J, Yu H, Wang F, et al. A comparison of thrombosis in total knee arthroplasty with and without a tourniquet: a meta-analysis of randomized controlled trials. J Orthop Surg Res. 2021;16:408.

28. Nicolaiciuc S, Probst P, von Eisenhart-Rothe R, et al. Modern total knee arthroplasty (TKA): with or without a tourniquet?. Surg Technol Int. 2019;35:336-40.

29. Smith TO, Hing CB. Is a tourniquet beneficial in total knee replacement surgery? A meta-analysis and systematic review. Knee. 2010;17:141-7.

30. Jouffliineau S, Thienpont E. Lower total blood loss in total knee arthroplasty with a low-pressure tourniquet than without. Acta Orthop Belg. 2021;87:461-8.

31. Zan PF, Yang Y, Fu D, et al. Releasing of tourniquet before wound closure or not in total knee arthroplasty: a meta-analysis of randomized controlled trials. J Arthroplasty. 2015;30:31-7.

32. Kim TK, Bamne AB, Sim JA, et al. Is lower tourniquet pressure during total knee arthroplasty effective? A prospective randomized controlled trial. BMC Musculoskelet Disord. 2019;20:275.

33. Hung SH, Chiu FY, Cheng MF. A comparative study of the hemodynamic and clinical effects of using or not tourniquet in total knee arthroplasty. J Chin Med Assoc. 2023;86:529-33.

34. Xu H, Yang J, Xie J, et al. Tourniquet use in routine primary total knee arthroplasty is associated with a higher transfusion rate and longer postoperative length of stay: a real-world study. BMC Musculoskelet Disord. 2020;21:620.

35. Andrade MAP, Monte LFR, Lacerda GC, et al. Are cementation quality and clinical outcomes affected by the use of tourniquet in primary total knee arthroplasty?. Arch Orthop Trauma Surg. 2022;142:845-50.