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Research Article

Efficacy of Tranexamic Acid on Perioperative Blood Loss in Hip Arthroplasty: A Comparative Study

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Abstract

Background: Using tranexamic acid (TXA) as a measure to ensure hemostasis during surgeries involving the hip region is a topic that is still debated, with scarce literature. The aim of this study was to assess the effectiveness of TXA administration in improving outcomes of hip arthroplasty.
Methods: This is a randomized comparative prospective study. It was conducted in the Department of Orthopedics, GMERS Medical College and Hospital, Vadodara, India, from January 2023 to December 2023 on 60 patients undergoing hip arthroplasty.
Results: The postoperative mean hemoglobin (Hb) value after 24 hours in the test group was 10.9 ± 1.6 g/dl while it was 10.1 ± 1.4 in the control group, which was statistically significant. The mean duration of surgery in the test group was 102.7 ± 28.2 minutes versus 125.2 ± 36.5 minutes in control with a P-value of 0.01, indicating less surgical duration in the test group.
Conclusion: TXA is an effective agent to reduce intraoperative blood loss, reduce surgical time, and improve post-operative Hb levels.

Keywords: Total Hip Arthroplasty; Tranexamic Acid; Surgical Blood Loss; Comparative Study

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Background

With the rapid advancements in the field of orthopedics and general surgical procedures, both minor as well as major orthopedic surgeries are much safer than they were even a decade ago (1). However, certain complications still plague them, one of which is blood loss during the perioperative period. Most orthopedic surgeries are associated with substantial amounts of blood loss (2). This, if left unmanaged, can lead to adverse patient outcomes and, in certain cases, even death (3).

It has been estimated that as much as half of all orthopedic surgeries are associated with transfusion of blood to the patient (4). This is especially the case in people who already have a lower-than-normal hemoglobin (Hb) level, as marked blood loss in them can lead to high morbidity and mortality.

Surgeries in and around the hip region have often been associated with a high frequency and quantity of blood loss (5). Therefore, ensuring successful outcomes in these surgeries requires special care in managing such blood loss. This is achieved by adequate intraoperative hemostasis, which prevents hematoma formation and minimizes blood loss. Successful hemostasis also leads to achieving a satisfactory postoperative range of movement and preventing adverse events such as pain, wound hematoma, seroma formation, and arthrofibrosis (3).

In these cases, blood transfusion can literally be a life-saving measure. However, certain intrinsic risks are also associated with blood transfusions (6). Blood transfusions are often expensive, with blood being a rare resource. Furthermore, certain risks of infection, immunosuppression, allergy, anaphylaxis, volume overloads, etc. have been documented with even compatible transfusions (7). Additionally, sociocultural factors also preclude blood transfusions in some instances. Therefore, blood transfusion should be considered the last step to achieve and maintain hemostasis during and after an orthopedic operation. For these reasons, other pharmacological and non-pharmacological methods have been explored that can help achieve and maintain hemostasis in the intra- and post-operative periods in orthopedic surgeries.

While hypotensive anesthetic procedures have shown some promise in this field, the procedures themselves have been observed to be associated with several complications (8). These include tissue hypoxia, coronary artery thrombosis, cardiac arrest, temporary and permanent neurologic deficit, failure of technique, resistance and rebound, postoperative reactionary hemorrhage, and tissue trauma (9). Since many of these adverse events are potentially dangerous, hypotensive anesthesia is uncommonly performed, especially in orthopedic surgery suites of hospitals with less advanced infrastructure, such as the secondary care institutions of developing countries like India. The other alternative that has been explored and shown to be effective and safe is the use of antifibrinolytic agents in managing blood loss. These pharmacological agents include drugs such as tranexamic acid (TXA), epsilon aminocaproic acid (EACA), aprotinin, etc. These drugs stabilize clots within the surgical wound by competitively inhibiting the plasminogen activators (10).

Of the antifibrinolytic agents, TXA has been the main focus of recent research, especially in developing countries such as India (11). This is because of its ease of

use, inexpensiveness, and wide availability in most surgical suites and healthcare institutions. Furthermore, it is one of the essential medicines per the list maintained by the World Health Organization (WHO) (12). TXA is a synthetic derivative of lysine, an amino acid. It exerts its antifibrinolytic effect via the reversible blockade of the lysine binding sites on the plasminogen molecules (13). Intravenous (IV) TXA has been used extensively to reduce hemorrhage during and after various surgical procedures, such as cardiac, orthopedic, and maxillofacial surgeries (14, 15). However, the use of the agent as a measure to ensure hemostasis during surgeries involving the hip region is a topic that is still debated, with scarce literature.

In this context, the present study was planned to assess the effectiveness of TXA as an agent to minimize intraoperative and postoperative blood loss in hip arthroplasty surgeries.

Methods

Study Area: This is a randomized comparative prospective study. It was conducted in the Department of Orthopedics, GMERS Medical College and Hospital, Vadodara, India, from January 2023 to December 2023.

The study population consisted of patients aged 18 years or above and scheduled to undergo hip arthroplasty in the study institution. Two groups of patients were recruited into the study. Group T patients received IV TXA at 10 mg/kg body weight via the IV route 10 minutes before the incision was made, and group C patients did not receive any TXA before the procedure.

Criteria of Selection of Patients

Inclusion criteria were as follows:

1. Patients of either sex, aged ≥18 years
2. Patients with Hb > 10 g/dl
3. Patients scheduled to undergo hip arthroplasty
4. Patients providing written informed consent to take part in the study.

Exclusion criteria were:

1. Patients with upper tract genitourinary bleeding, e.g., kidney, ureter
2. Patients with a history of subarachnoid bleeding
3. Patients with active intravascular clot and disseminated intravascular coagulation
4. Patients with renal failure and abnormal renal parameters
5. Patients with thromboembolic disorders
6. Patients with documented coagulopathy
7. Patients with hypersensitivity reaction to TXA.

Patient Allocation, Operation Procedure, and Data Gathering: Those who met the inclusion criteria were recruited into the study. After explaining the procedure and methodology of the research to the guardians and obtaining written informed consent from them, a predesigned, pretested researcher-administered questionnaire was used to obtain data relevant to the sociodemographic and clinical characteristics of the study participants. The intraoperative blood loss was evaluated based on mop count and blood collection in the suction apparatus, while postoperative blood was evaluated based on 24-hour postop Hb level.

Then, 5 ml venous blood was collected from each patient and sent to the institutional pathology laboratory in an ethylenediamine tetraacetic acid (EDTA) vial to estimate complete blood count (CBC) and Hb estimation. Each patient underwent hip arthroplasty [total hip arthroplasty (THA) or bipolar hemiarthroplasty] following the standard surgical procedure. In group T patients (TXA group), an IV bolus dose of TXA 10 mg/kg was administered 10 minutes before the incision. At the same time, it was not given to the patients in group C (control group). Another 10 mg/kg TXA bolus was administered topically to the group T patients during the intraoperative period post-incision. 24 hours after the surgery, 5 ml of venous blood was again taken from each patient and sent in an EDTA vial to the institutional pathology laboratory for CBC estimation. The blood collected in the suction apparatus during surgery, the number of mops used in the intraoperative period, and collection in the drain at 24 hours of the postoperative period were estimated as measures of blood loss. No drain was put in any of the patients.

TXA and Its Pharmacokinetics: TXA is a synthetic lysine derivative that reduces the dissolution of hemostatic fibrin by plasmin. It exerts its anti-fibrinolytic effects by the reversible blockade of the lysine binding site of plasminogen molecules. The effect of TXA is mediated by a reversible interaction occurring at multiple sites of the plasminogen molecule. The saturation of the binding sites of the plasminogen molecules by TXA leads to its displacement from the surface of fibrin. The drug acts within 2-3 hours after oral administration and immediately after IV administration. It reduces the fibrin lysis rate by 20-60 percent (16).

The plasma protein binding of TXA is about 3% at the therapeutic plasma level and seems to be fully accounted for by its binding to plasminogen. TXA does not bind to serum albumin. After an IV dose of 1 g, the plasma concentration-time curve shows a triexponential decay with a half-life of about 2 hours for the terminal elimination phase. The initial volume of distribution is about 9 to 12 liters. Only a small fraction of the drug is metabolized, and it gets eliminated via urinary excretion. Glomerular filtration excretes 95% of the drug unchanged. Within the first 24 hours, 90% of drugs get eliminated. The elimination of the drug is estimated to be around 2 hours.

TXA diffuses rapidly into the joint fluid and the synovial membrane. In the joint fluid, the same concentration is obtained as in the serum. The biological half-life of TXA in the joint fluid is about 3 hours. Common adverse effects of TXA include headache, dizziness, shortness of breath, nausea, diarrhea, and watery eyes. Rapid IV infusion of the drug can cause hypotension. TXA is contraindicated in patients with subarachnoid hemorrhage and patients with a history of thromboembolic episodes. There is also a relative contraindication for patients with heart, kidney, and liver diseases (17).

Results

In this prospective study, 60 patients were operated for hip arthroplasty. The majority of patients (31/60) were aged 60-79 years, with 55% (33/60) being women and 45% (27/60) men.

Out of 60 patients, 27 underwent THA (45%), and 33 (55%) patients underwent hemiarthroplasty (55%). In group T, out of 30, 13 patients underwent THA (43.3%), and 17 patients underwent hemiarthroplasty (56.7%). In group C, 14 patients underwent THA (46.6%), and 17 patients underwent hemiarthroplasty (53.4%).

Baseline Hb levels were similar between group T (12.4 ± 1.7 g/dl) and group C (11.8 ± 1.7 g/dl) (P > 0.05).

Intraoperatively, the mean amount of blood collected in the suction apparatus for the study participants in group T was 268.3 ± 96.1 ml, while that in group C was

301.7 ± 93.5 ml, which was significantly higher than the former.

Study groups did not differ from each other statistically significantly with respect to the number of mops required intraoperatively.

The mean duration of surgery in group T was 102.7 ± 28.2 minutes, while that in group C was 125.2 ± 36.5 minutes. It was seen that the mean duration of surgery for group T participants was statistically significantly lower than that in the control group patients.

The mean Hb level in group T was significantly higher than in group C (10.9 ± 1.6 g/dl vs. 10.1 ± 1.4 g/dl, P < 0.05).

Discussion

In the present study, the antifibrinolytic agent TXA was assessed as a drug to minimize intraoperative and postoperative blood loss in hip arthroplasty surgeries. Two groups of 30 patients each were selected, with group T receiving 10 mg/kg TXA 10 minutes before the surgery and intralesionally in the intraoperative period, and group C being the control group, who were not given TXA during their surgery. The findings of the present study are discussed henceforth.

It was observed that the age of the participants ranged from 19 to 89 years, with the mean age of the TXA group patients being 56.1 ± 16.7 years, and that of the control group being 58.7 ± 16.8 years. Most of the study participants were between 60 and 79 years old, predominantly representing a middle-aged demographic population. This age distribution is similar to what was seen in other studies, where the procedure is commonly indicated for conditions such as osteoarthritis (OA), rheumatoid arthritis (RA), and other degenerative joint diseases that escalate with age. The majority of patients being between 60 and 79 years indicates the effect of aging on joint health, exacerbated by lifestyle factors, genetic predisposition, and possibly the onset of chronic conditions prevalent in this demographic population. Similar mean age was reported in the studies by Moskal et al. (18) and Lin et al. (11).

Most of the study participants were women (53.3% in group T and 56.7% in group C, P = 0.795). This observation is indicative of the gender-specific prevalence of conditions necessitating hip arthroplasty, particularly in the Indian context. Firstly, the higher incidence of OA among women, especially post-menopausal women, due to hormonal changes and decreased estrogen levels, significantly contributes to the degradation of joint health. This factor is crucial in understanding the gender disparity, as OA is a leading indication for hip arthroplasty (19). In many Indian communities, women are engaged in activities requiring prolonged periods of squatting or sitting on the floor, which may exacerbate hip joint stress and degeneration over time (20). The findings of the present study are in line with the observations made in other studies conducted globally, with authors such as Gandhi et al. (21) and Wang et al. (22) in their systematic review and meta-analyses reporting a female preponderance in patients requiring hip arthroplasty surgeries.

It was observed that the mean duration of surgery in group T was 102.7 ± 28.2 minutes, while that in group C was 125.2 ± 36.5 minutes. It was seen that the mean duration of surgery for group T participants was statistically significantly lower than that in the control group patients. This observation suggests that the administration of TXA may contribute to more efficient surgical procedures by reducing blood loss and improving the visibility of the surgical field. Intraoperative bleeding can often complicate the surgical process, constraining additional time for hemostasis and blood management. By effectively minimizing bleeding, TXA facilitates a smoother and potentially quicker surgical procedure, allowing for a more streamlined operation and potentially reducing the risk of complications associated with prolonged surgery. Furthermore, the reduction in operative time has implications for overall surgical efficiency, resource utilization, and patient outcomes. Shorter surgery durations can lead to less time under anesthesia, potentially reducing the risk of anesthesia-related complications and improving postoperative recovery times. Additionally, improved operative efficiency can enhance hospital throughput, allowing for the treatment of more patients within the same time frames and resources (23).

The mean Hb level of the patients of group T was 12.4 ± 1.7 g/dl, while that of the group C was 11.8 ± 1.7 g/dl at baseline. The two study groups did not differ statistically significantly with respect to their Hb values at baseline. This parity at baseline is crucial as it ensures that any observed postoperative differences in Hb levels can be attributed with greater confidence to the intervention under study rather than preexisting disparities. At the 24-hour postoperative mark, a noteworthy divergence emerged between the two groups. Participants in group T, who received TXA, exhibited a mean Hb level of 10.9 ± 1.6 g/dl, contrastingly higher than the 10.1 ± 1.4 g/dl observed in group C. This difference, upon statistical analysis, was identified as significant, underscoring the efficacy of TXA in mitigating blood loss associated with hip arthroplasty surgery. Similarly, lower drop in postoperative Hb levels in patients receiving TXA in total hip replacement (THR) surgeries have also been reported by authors such as Chen et al. (24), Peck et al. (25), Wind et al. (26), Gandhi et al. (21) and Wang et al. (22). TXA, an antifibrinolytic agent, functions by inhibiting the conversion of plasminogen to plasmin, thereby stabilizing fibrin clots and reducing bleeding. The observed higher postoperative Hb levels in the TXA group suggest that the drug effectively reduced intraoperative and immediate postoperative bleeding, preserving Hb levels and potentially reducing the need for postoperative blood transfusions (12). The significance of this finding cannot be overstated. Perioperative blood management is a critical aspect of hip arthroplasty, with implications for patient recovery, the risk of complications, and overall outcomes. Blood loss during and after hip arthroplasty can lead to anemia, increased transfusion rates, and associated risks such as transfusion reactions and infections. By demonstrating a statistically significant reduction in blood loss as evidenced by higher postoperative Hb levels, TXA administration presents a compelling case for its routine use in hip arthroplasty patients (10). Furthermore, the implications of this study extend beyond the immediate perioperative period. The maintenance of higher Hb levels postoperatively may facilitate quicker patient recovery, reduce the length of hospital stay, and diminish the overall burden on healthcare resources. Additionally, by potentially reducing the need for blood transfusions, TXA use aligns with broader goals of patient safety and cost-effectiveness in surgical care.

It was further seen that the mean amount of blood collected in the suction apparatus in patients of group T was significantly lower than that collected for the group C

patients (268.3 ± 96.1 ml vs. 301.7 ± 93.5 ml, P = 0.021). However, the number of mops required in the two groups did not differ statistically significantly, although it was higher in the group C patients as compared to the group T patients (4.3 ± 0.8 vs. 4.1 ± 0.7, respectively). Gianakos et al. in their meta-analysis of 28 randomized controlled trials (RCTs) also reported a significant lowering of intraoperative blood loss in patients receiving TXA as compared to controls (17). In another meta-analysis, Chen et al. also reported that there was a significant decrease in intraoperative blood loss in patients receiving TXA as compared to those not receiving the drug in the preoperative period (24).

The reduced volume of blood collected in the suction apparatus in group T directly reflects the antifibrinolytic mechanism of TXA, which stabilizes the formation of blood clots, and thus reduces active bleeding. The effectiveness of TXA in decreasing the overall blood loss during surgery is thereby highlighted, potentially contributing to lessened transfusion requirements and improved patient outcomes. Conversely, the non-significant difference in the number of mops required might suggest that while TXA effectively reduces the volume of free-flowing blood that can be suctioned, it has less impact on blood loss that is absorbed or handled by surgical mops. Surgical mops are often used for blotting and absorbing blood from surfaces not easily accessible by suction, indicating that while TXA reduces overall bleeding, it might not significantly alter the distribution of blood loss within the surgical field (27). However, a higher count of surgical mops used in the control group patients reiterates the effect of TXA in the reduction of blood loss in patients receiving the agent. Reduced intraoperative blood loss can contribute to faster patient recovery, decrease the likelihood of postoperative complications associated with significant blood loss, and potentially shorten hospital stays (28).

Therefore, the findings of the present study indicate that TXA, when administered in the pre-operative and intraoperative period, is an effective agent in the prevention of blood loss in patients undergoing either THA or bipolar hemiarthroplasty surgeries. A larger sample size or a multicenter study would have been more conclusive with respect to the conducted study.

Conclusion

Our study found that TXA was an effective agent for reducing intraoperative blood loss and minimizing the drop in postoperative Hb levels in hip arthroplasty. These results suggest that TXA can play a valuable role in improving perioperative outcomes by preserving Hb levels and potentially reducing the need for blood transfusions. It is recommended that further research with larger sample sizes be conducted to validate these findings.

Conflict of Interest

The authors declare no conflict of interest in this study.

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References

1. Sculco PK, McLawhorn AS, Fehring KA, De Martino I. The future of social media in orthopedic surgery. *Curr Rev Musculoskelet Med*. 2017;10(2):278-9. doi: 10.1007/s12178-017-9412-9. [PubMed: 28456946]. [PubMed Central: PMC5435643].
2. Theusinger OM, Kind SL, Seifert B, Borgeat L, Gerber C, Spahn DR. Patient blood management in orthopaedic surgery: a four-year follow-up of transfusion requirements and blood loss from 2008 to 2011 at the Balgrist University Hospital in Zurich, Switzerland. *Blood Transfus*. 2014;12(2):195-203. doi: 10.2450/2014.0306-13. [PubMed: 24931841]. [PubMed Central: PMC4039701].
3. Sizer SC, Cherian JJ, Elmallah RD, Pierce TP, Beaver WB, Mont MA. Predicting Blood Loss in Total Knee and Hip Arthroplasty. *Orthop Clin North Am*. 2015;46(4):445-59. doi: 10.1016/j.ocl.2015.06.002. [PubMed: 26410634].
4. Mikhail C, Pennington Z, Arnold PM, Brodke DS, Chapman JR, Chutkan N, et al. Minimizing Blood Loss in Spine Surgery. *Global Spine J*. 2020;10(1 Suppl):71s-83s. doi: 10.1177/2192568219868475. [PubMed: 31934525]. [PubMed Central: PMC6947684].
5. Lee JH, Han SB. Patient Blood Management in Hip Replacement Arthroplasty. *Hip Pelvis*. 2015;27(4):201-8. doi: 10.5371/hp.2015.27.4.201. [PubMed: 27536627]. [PubMed Central: PMC4972790].
6. Carling MS, Jeppsson A, Eriksson BI, Brisby H. Transfusions and blood loss in total hip and knee arthroplasty: a prospective observational study. *J Orthop Surg Res*. 2015;10:48. doi: 10.1186/s13018-015-0188-6. [PubMed: 25889413]. [PubMed Central: PMC4383080].
7. Miao K, Ni S, Zhou X, Xu N, Sun R, Zhuang C, et al. Hidden blood loss and its influential factors after total hip arthroplasty. *J Orthop Surg Res*. 2015;10:36. doi: 10.1186/s13018-015-0185-9. [PubMed: 25889223]. [PubMed Central: PMC4367912].
8. Cohn MR, Levack AE, Trivedi NN, Villa JC, Wellman DS, Lyden JP, et al. The Hip Fracture Patient on Warfarin: Evaluating Blood Loss and Time to Surgery. *J Orthop Trauma*. 2017;31(8):407-13. doi: 10.1097/bot.0000000000000857. [PubMed: 28445186].
9. Nielson E, Hennrikus E, Lehman E, Mets B. Angiotensin axis blockade, hypotension, and acute kidney injury in elective major orthopedic surgery. *J Hosp Med*. 2014;9(5):283-8. doi: 10.1002/jhm.2155. [PubMed: 24464761].
10. Lerman DM, Rapp TB. Minimizing Blood Loss in Orthopaedic Surgery The Role of Antifibrinolytics. *Bull Hosp Jt Dis (2013)*. 2015;73(2):83-9. [PubMed: 26517160].
11. Lin ZX, Woolf SK. Safety, Efficacy, and Cost-effectiveness of Tranexamic Acid in Orthopedic Surgery. *Orthopedics*. 2016;39(2):119-30. doi: 10.3928/01477447-20160301-05. [PubMed: 26942474].
12. Danninger T, Memtsoudis SG. Tranexamic acid and orthopedic surgery-the search for the holy grail of blood conservation. *Ann Transl Med*. 2015;3(6):77. doi: 10.3978/j.issn.2305-5839.2015.01.25. [PubMed: 25992376]. [PubMed Central: PMC4416949].
13. Thorsen S, Clemmensen I, Sottrup-Jensen L, Magnusson S. Adsorption to fibrin of native fragments of known primary structure from human plasminogen. *Biochim Biophys Acta*. 1981;668(3):377-87. doi: 10.1016/0005-2795(81)90171-9. [PubMed: 7236714].
14. Ido K, Neo M, Asada Y, Kondo K, Morita T, Sakamoto T, et al. Reduction of blood loss using tranexamic acid in total knee and hip arthroplasties. *Arch Orthop Trauma Surg*. 2000;120(9):518-20. doi: 10.1007/s004029900132. [PubMed: 11011672].
15. Katsaros D, Petricevic M, Snow NJ, Woodhall DD, Van Bergen R. Tranexamic acid reduces postbypass blood use: a double-blinded, prospective, randomized study of 210 patients. *Ann Thorac Surg*. 1996;61(4):1131-5. doi: 10.1016/0003-4975(96)00022-7. [PubMed: 8607670].
16. Wellington K, Wagstaff AJ. Tranexamic acid: a review of its use in the management of menorrhagia. *Drugs*. 2003;63(13):1417-33. doi: 10.2165/00003495-200363130-00008. [PubMed: 12825966].
17. Gianakos AL, Hurley ET, Haring RS, Yoon RS, Liporace FA. Reduction of Blood Loss by Tranexamic Acid Following Total Hip and Knee Arthroplasty: A Meta-Analysis. *JBJS Rev*. 2018;6(5):e1. doi: 10.2106/jbjs.Rvw.17.00103. [PubMed: 29738409].
18. Moskal JT, Capps SG. Meta-analysis of Intravenous Tranexamic

Acid in Primary Total Hip Arthroplasty. *Orthopedics*. 2016;39(5):e883-92. doi: 10.3928/01477447-20160526-02. [PubMed: 27248332].
19. Inacio MC, Ake CF, Paxton EW, Khatod M, Wang C, Gross TP, et al. Sex and risk of hip implant failure: assessing total hip arthroplasty outcomes in the United States. *JAMA Intern Med*. 2013;173(6):435-41. doi: 10.1001/jamainternmed.2013.3271. [PubMed: 23420484].
20. Basques BA, Bell JA, Fillingham YA, Khan JM, Della Valle CJ. Gender Differences for Hip and Knee Arthroplasty: Complications and Healthcare Utilization. *J Arthroplasty*. 2019;34(8):1593-7.e1. doi: 10.1016/j.arth.2019.03.064. [PubMed: 31003781].
21. Gandhi R, Evans HM, Mahomed SR, Mahomed NN. Tranexamic acid and the reduction of blood loss in total knee and hip arthroplasty: a meta-analysis. *BMC Res Notes*. 2013;6:184. doi: 10.1186/1756-0500-6-184. [PubMed: 23651507]. [PubMed Central: PMC3655041].
22. Wang C, Xu GJ, Han Z, Ma JX, Ma XL, Jiang X, et al. Topical application of tranexamic acid in primary total hip arthroplasty: A systemic review and meta-analysis. *Int J Surg*. 2015;15:134-9. doi: 10.1016/j.ijsu.2014.12.023. [PubMed: 25576011].
23. Haratian A, Shelby T, Hasan LK, Bolia IK, Weber AE, Petrigliano FA. Utilization of Tranexamic Acid in Surgical Orthopaedic Practice: Indications and Current Considerations. *Orthop Res Rev*. 2021;13:187-99. doi: 10.2147/orr.S321881. [PubMed: 34703327]. [PubMed Central: PMC8541761].
24. Chen S, Wu K, Kong G, Feng W, Deng Z, Wang H. The efficacy of topical tranexamic acid in total hip arthroplasty: a meta-analysis. *BMC Musculoskelet Disord*. 2016;17:81. doi: 10.1186/s12891-016-0923-0. [PubMed: 26878845]. [PubMed Central: PMC4754977].
25. Peck J, Kepecs DM, Mei B, Safir OA, Backstein D, Gross AE, et al. The Effect of Preoperative Administration of Intravenous Tranexamic Acid During Revision Hip Arthroplasty: A Retrospective Study. *J Bone Joint Surg Am*. 2018;100(17):1509-16. doi: 10.2106/jbjs.17.01212. [PubMed: 30180060].
26. Wind TC, Barfield WR, Moskal JT. The effect of tranexamic acid on transfusion rate in primary total hip arthroplasty. *J Arthroplasty*. 2014;29(2):387-9. doi: 10.1016/j.arth.2013.05.026. [PubMed: 23790499].
27. Kayupov E, Fillingham YA, Okroj K, Plummer DR, Moric M, Gerlinger TL, et al. Oral and Intravenous Tranexamic Acid Are Equivalent at Reducing Blood Loss Following Total Hip Arthroplasty: A Randomized Controlled Trial. *J Bone Joint Surg Am*. 2017;99(5):373-8. doi: 10.2106/jbjs.16.00188. [PubMed: 28244907].
28. Haynes JA, Stambough JB, Sassoon AA, Johnson SR, Clohisy JC, Nunley RM. Contemporary Surgical Indications and Referral Trends in Revision Total Hip Arthroplasty: A 10-Year Review. *J Arthroplasty*. 2016;31(3):622-5. doi: 10.1016/j.arth.2015.09.026. [PubMed: 26541220].