COMPARATIVE ANALYSIS OF INTRAVENOUS TRANEXAMIC ACID AND TOPICAL TRANEXAMIC ACID IN REDUCING POSTOPERATIVE BLOOD LOSS IN LUMBAR SPINE FUSION SURGERY

Dr. Kunal Shankar
Department of Orthopaedics
Mahatma Gandhi Medical College and Research Institute
Dr.Rajarasan.D(Asst.Prof)
Dr.BalaEshwar(Asst.Prof)
Prof. Dr. Krishna Gopal. R
Sri Balaji Vidyapeeth (University),Mahatma Gandhi Medical College and Research Institute

Background: Lumbar degenerative disease frequently necessitates surgical intervention, with intraoperative and postoperative blood loss posing a significant challenge. Tranexamic acid (TXA), an antifibrinolytic agent, has proven efficacy in reducing blood loss; however, the optimal route of administration in spine surgery remains uncertain. **Objective:** To evaluate and compare the effectiveness of intravenous versus topical TXA in reducing postoperative blood loss among patients undergoing lumbar spine fusion surgery. **Materials and Method:** The present prospective observational study enrolled 40 patients undergoing lumbar spinal fusion. Participants were allocated into two groups: Group A received intravenous TXA (15 mg/kg diluted in 100 mL saline, administered 15 minutes before incision closure), while Group B received topical TXA (2 g soaked in a gelatin sponge, applied intraoperatively). Outcomes assessed included postoperative drain output, perioperative hemoglobin changes, and hospital stay duration. Statistical analysis was performed using appropriate tests, with $p < 0.05$ considered significant. **Results:** Baseline demographic characteristics were comparable, except for a significantly higher BMI in the intravenous group ($p = 0.022$). The topical group had a higher mean drain output (173.75 ± 58.41 mL) compared to the intravenous group (141 ± 48.33 mL), though this difference did not reach statistical significance ($p = 0.060$). Both groups experienced a postoperative hemoglobin drop, but the difference was not statistically significant ($p = 0.760$). The duration of hospital stay was longer in the topical group (8.95 ± 3.28 days) compared to the intravenous group (7.4 ± 3.21 days), without statistical significance ($p = 0.139$). **Conclusion:** Intravenous and topical TXA demonstrated comparable efficacy and safety in reducing postoperative blood loss following lumbar spine fusion. Intravenous TXA showed a trend toward lower drain output, while topical TXA remains a viable alternative, especially for patients at risk of systemic side effects. Further randomized controlled trials are warranted to establish definitive recommendations.

Keywords: Tranexamic acid; Lumbar spine fusion surgery; Postoperative blood loss; Intravenous; Topical

INTRODUCTION

Lumbar degenerative disease commonly manifests with lower back pain, often requiring surgical intervention. Despite advances in technique, excessive intraoperative blood loss remains a major concern, particularly in spinal deformity surgery, and is associated with anemia, complications, and increased mortality [1–3]. Blood transfusions, though frequently necessary, introduce risks including infection, hemolysis, hematoma, anaphylaxis, and higher healthcare costs [1,4]. To mitigate perioperative blood loss, strategies include meticulous hemostasis, controlled hypotension, and antifibrinolytic agents [5]. Among these, tranexamic acid (TXA) is most effective, acting by inhibiting fibrinolysis and significantly reducing blood loss during spine surgery [6].

Tranexamic acid (TXA) is a synthetic lysine analogue with antifibrinolytic properties, acting by competitively binding to lysine sites on plasminogen, plasmin, and tissue plasminogen activator, thereby inhibiting fibrinolysis [7]. Intravenous administration (ivTXA), usually given as a pre-incision bolus followed by infusion, is widely practiced and effectively reduces blood loss in surgery [8,9]. However, systemic use is associated with potential adverse effects, including deep vein thrombosis (DVT), pulmonary embolism (PE), and myocardial infarction (MI) [10,11]. Consequently, ivTXA is avoided in patients with prior histories of stroke, MI, thromboembolism, or seizure disorders [12–14]. Reports suggest a 4.1-fold increase in postoperative seizures in adult cardiac surgery with ivTXA, particularly at higher doses [15–17].

To reduce systemic exposure, topical TXA (tTXA) has been explored, offering high local drug concentration at the bleeding site with minimal systemic absorption [7]. This approach may lower the risks of thromboembolism, renal impairment, and seizures linked to ivTXA. tTXA has shown success in reducing blood loss and transfusion requirements in hip and knee arthroplasty [18-20]. However, evidence in spine surgery remains limited, with uncertainty regarding its comparative efficacy to ivTXA.

Given this gap, the present study was conducted to evaluate and compare the effectiveness of intravenous versus topical TXA in reducing postoperative drain output following lumbar spine fusion surgery.

MATERIALS AND METHOD

The present prospective observational study was conducted in the Department of Orthopaedics, Mahatma Gandhi Medical College and Research Institute (MGMC&RI), Puducherry, among 40 patients undergoing lumbar spinal fusion surgeries who fulfilled the inclusion and exclusion criteria. The study was carried out over a period of 18 months following approval from the Institutional Ethics Committee, and informed written consent was obtained from all participants after providing a detailed explanation of the procedure.

A total of 40 patients were included in the study, with 20 patients assigned to each group. Patients aged between 18 and 65 years of either sex, with an American Society of Anesthesiologists (ASA) physical status I to III, and a body mass index (BMI) less than 35 kg/m² were considered eligible. Patients were excluded if they were unwilling or unable to understand the study protocol, had a history of thromboembolism or evidence of an existing thrombus, were

on antiplatelet therapy within the past 6 months, or had coagulation dysfunction. Individuals with cardiovascular, hepatic, renal, or hematological disorders, known allergy to tranexamic acid, pathological or osteoporotic fractures, previous spinal surgery, or multiple injuries were also excluded.

The study population was divided into two groups n **Group A (intravenous group)**, tranexamic acid (15 mg/kg dissolved in 100 mL of normal saline) was administered intravenously 15 minutes before incision closure. In **Group B (topical group)**, a gelatin sponge saturated with tranexamic acid (2 g soaked for 5 minutes) was placed flat in the surgical field before closure. The wound was irrigated, and a drain was fixed for all patients at the end of surgery, with drains removed after 48 hours. Postoperatively, patients were followed for drain output at 48 hours, and blood samples, including complete blood counts and hemoglobin levels, were obtained.

At the end of the surgery the wound was irrigated with the solution and drain fixed for all the patients. All drains were removed 48 hours after placement.

Post-operatively, patients were followed up with drain output for 48 hours. Blood samples such as complete blood count (haemoglobin level. etc) was taken and 48 hours drain output was measured.

All data were entered in Microsoft Excel and analyzed using appropriate statistical tests (Chi-square test for categorical variables, independent t-test for continuous variables, and Mann–Whitney U test for non-parametric data). A p-value of <0.05 was considered statistically significant.

RESULTS

Table/figure 1: Age and gender wise Distribution of Study subjects

Variables		**Intravenous Group**		**Topical Group**	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Age Range (years)	<30	1	5.00	0	0.00
	31-40	2	10.00	3	15.00
	41-50	9	45.00	7	35.00
	51-60	4	20.00	5	25.00
	61-70	3	15.00	5	25.00
	>70	1	5.00	0	0.00
	Mean ±SD	49.45 ±11.57		50.8±10.54	
Gender	**Male**	**3**	**15.00**	**7**	**35.00**
	Female	**17**	**85.00**	**13**	**65.00**

Total	20	100.00	20	100.00

The **table/figure** 1 categorizes the participants by age range across two treatment groups: Intravenous and Topical. The majority of participants in both groups fall within the 41–50 and 51–60 years age brackets. Specifically, 45% of patients in the intravenous group were aged 41–50 years, while the same age group constituted 35% in the topical group. The topical group had a slightly higher representation in the 51–60 and 61–70 years range (25% each), compared to 20% and 15% respectively in the intravenous group. The mean ages were comparable—49.45 ± 11.57 years for the intravenous group and 50.8 ± 10.54 years for the topical group. The p-value of 0.690, indicating no statistically significant difference in age distribution between the groups. The intravenous group had a predominance of female subjects (85%), whereas the topical group had a relatively more balanced distribution with 65% females and 35% males. The p-value of 0.14, indicating that the difference in gender distribution between the two groups was not statistically significant.

Table/figure 2: Mean BMI among Study subjects

Group	**Mean (Kg/M^2)**	**SD(Kg/M^2)**	**P-value**
Intravenous Group	**29.2**	**2.37**	**0.022***
Topical Group	**26.75**	**3.95**	

The table/figure 2 compares the Body Mass Index (BMI) between the two groups. Participants in the intravenous group had a higher mean BMI of 29.2 kg/m² (SD = 2.37) than those in the topical group, who had a mean BMI of 26.75 kg/m² (SD = 3.95). The p-value of 0.022, which is statistically significant ($p<0.05$). This indicates a significant difference in BMI between the two groups, suggesting the intravenous group had a higher average body mass.

Table/figure 3: Mean Drain Output among Study subjects

Group	**Mean (ml)**	**SD (ml)**	**p-value**
Intravenous Group	**141.00**	**48.33**	**0.060**
Topical Group	**173.75**	**58.41**	

The table/figure 3 shows the postoperative drain output in milliliters for each group. The topical group had a higher mean drain output (173.75 ml ± 58.41) compared to the intravenous group (141 ml ± 48.33). Although the difference suggests a trend towards

higher drainage in the topical group, A p-value of 0.060 indicate that this difference was not statistically significant at the conventional threshold ($p<0.05$).

Table/figure 4: Mean Hb among Study subjects

Group	Time Point	Mean Hb (gm%)	SD	p-value
Intravenous Group	Pre-op	12.00	1.10	0.080
	Post-op	10.60	1.00	
Topical Group	Pre-op	11.85	1.30	0.070
	Post-op	10.40	1.20	

Both groups showed a **decrease in haemoglobin levels** postoperatively; however, the reductions were **not statistically significant** ($p > 0.05$) (table/figure 4), suggesting that intraoperative blood loss or fluid-related effects were similar and not substantial enough to reach significance.

Table/figure 5: Comparison of Haemoglobin Drop

Group	Mean Hb Drop (gm%)	SD	p-value
Intravenous Group	1.40	0.50	
Topical Group	1.45	0.60	0.760

The table/figure 5 shows topical group had a slightly higher mean hemoglobin drop (1.45 gm%) than the intravenous group (1.40 gm%), but the difference was **not statistically significant** ($p = 0.760$), indicating that both routes resulted in similar postoperative hemoglobin reductions.

Table/figure 6: Hospital stay among study subjects

Group	Median (days)	Mean (days)	SD	p-value
Intravenous Group	5	7.4	3.21	0.139
Topical Group	10	8.95	3.28	

The table/figure 6 presents the duration of hospital stay for both groups. The topical group had a longer median hospital stay of 10 days and a mean of 8.95 days (SD =

3.28), whereas the intravenous group had a median of 5 days and a mean of 7.4 days (SD = 3.21). The t-value was 1.5 and the p-value was 0.139, suggesting that while the topical group stayed longer on average, the difference was not statistically significant.

DISCUSSION

Spinal surgery is often accompanied by substantial blood loss during and after the operation, which can lead to acute anaemia and potentially severe complications. To address this anaemia, blood transfusions are frequently necessary, but they come with their own set of risks, including the transmission of diseases, haemolytic reactions, and anaphylactic responses. Furthermore, blood transfusions also impose a significant economic burden on patients and healthcare systems [21]. Hence, the present study was carried to compare the efficacy of intravenous versus topical administration of tranexamic acid in reducing post operative drain output in lumbar spine fusion surgery and found that both intravenous and topical tranexamic acid (TXA) are effective in reducing postoperative blood loss in lumbar spine fusion surgery. Although the intravenous group had a lower mean drain output compared to the topical group, the difference was not statistically significant ($p = 0.060$).

A total of 40 patients were enrolled in the present study and were divided into two groups: Group A, which received intravenous Tranexamic acid (15mg/kg), and Group B, which received topical Tranexamic acid (2g) via gelatin sponge saturation.

In the present study, the majority of participants in both the intravenous (IV) and topical groups were between 41-60 years old, with mean ages of 49.45 ± 11.57 years and 50.8 ± 10.54 years, respectively. The difference in age distribution between the two groups was not statistically significant (chi-square = -3.06, $p = 0.690$). Similarly, the gender distribution, with 85% females in the IV group and 65% females in the topical group, did not differ significantly between the groups (chi-square = -2.13, $p = 0.14$). However, the mean Body Mass Index (BMI) was significantly higher in the IV group (29.2 kg/m²) compared to the topical group (26.75 kg/m²), with a t-test value of -2.37 and a p-value of 0.022, indicating statistical significance.

In the present study, the postoperative drain output in milliliters for each group. The topical group had a higher mean drain output (173.75 ml ± 58.41) compared to the intravenous group (141 ml ± 48.33). Although the difference suggests a trend towards higher drainage in the topical group, the t-value of 1.93 and a p-value of 0.060 indicate that this difference was not statistically significant at the conventional threshold ($p<0.05$). Our results are consistent with analysis carried by Xiong Z et al [4] that found intravenous administration of TXA did not have a significant effect on the decrease of blood loss and blood transfusion rate compared with the topical group. In line with our study, Mu X et al [1] found that both the intravenous TXA group and the topical TXA group had significantly lower postoperative drainage volume, number of blood transfusions, length of hospital stay, and extubation time compared to the placebo group and consistent with the present study. The study also found significant differences

among the three groups in intraoperative blood loss, visible blood loss, and postoperative hemoglobin and hematocrit levels, with the TXA groups generally performing better than the placebo group. Another concordant study by Krohn CD et al [22] involved 30 patients undergoing screw fixation of the lumbar spine for low back pain, with 16 patients randomized to receive topical tranexamic acid and the results showed that the median blood loss was reduced by half in the tranexamic acid group, from 525 ml to 252 ml ($p = 0.02$). Further, their study measured postoperative blood loss at 18 hours and concentrations of plasmin/alpha2-antiplasmin (PAP) and D-dimer in arterial and drained blood and the increase in PAP and D-dimer concentrations in drained blood after one hour was significantly lower in the tranexamic acid group compared to the control group. The study concluded that topical application of tranexamic acid in the wound reduces blood loss by up to 50% in major orthopedic surgery, likely by preventing excessive fibrinolysis. Similarly, in a meta-analysis by Hui S et al [6] found that topical Tranexamic Acid (tTXA) was associated with a weighted mean difference (WMD) of -160.62 ml (95% CI: -203.41 to -117.83; $p < 0.00001$) in postoperative drainage output and a WMD of -0.75 days (95% CI: -1.09 to -0.40; $p < 0.0001$) in duration and concluded that tTXA use in spinal surgeries significantly reduces postoperative drainage than placebo. Luo W et al [22] conducted a meta-analysis to evaluate the efficacy and safety of topical tranexamic acid (TXA) in spine surgery and the results showed significant differences in total blood loss (MD = -267.53, 95% CI -373.04 to -106.02, $P < 0.00001$) and drainage volume (MD = -157.00, 95% CI -191.17 to -122.84, $P < 0.00001$) compared to group in which tranexamic acid was not applied. In another comparable study by Ren Z et al [7], the study compared topical application of tranexamic acid with those in which it was not compared and found that in the topical Tranexamic Acid (tTXA) group, the total blood loss (TBL), postoperative blood loss (PBL) were significantly lower than those in the control group. Specifically, the total blood loss was 550 ± 268 mL in the tTXA group versus 833 ± 298 mL in the control group. Postoperative blood loss was 53.5 ± 43.9 mL in the tTXA group versus 136.7 ± 87.9 mL in the control group. These differences were statistically significant, with P-values of less than 0.001 for all comparisons. Tranexamic acid (TXA) primarily exerts its effect by inhibiting the binding of plasminogen and tissue plasminogen activator to fibrin. This inhibition reduces the conversion of plasminogen to plasmin, a serine protease that breaks down fibrin clots. By preventing the formation of plasmin, TXA effectively stabilizes fibrin clots and reduces bleeding [23]. On the contrast, in study by Kitaguchi K et al [24], the total postoperative blood loss was significantly lower in the topical tranexamic acid group (350.8 ± 132.6 ml) compared to both the intravenous tranexamic acid group (566.4 ±178.8 ml) and the control group (704.4 ± 225.9 ml), with p-values of less than 0.01 for both comparisons.

In the present study, preoperative haemoglobin was slightly higher in the intravenous group (12.00 ± 1.10 gm%) compared to the topical group (11.85 ± 1.30 gm%), though

this difference was not statistically significant (t = 0.45, p = 0.650). Similarly, postoperative haemoglobin values were also higher in the intravenous group (10.60 ± 1.00 gm%) than in the topical group (10.40 ± 1.20 gm%), but again, the difference did not reach statistical significance (t = -0.60, p = 0.550).

These findings indicate that both intravenous and topical TXA were similarly effective in maintaining postoperative haemoglobin levels. The drop in haemoglobin from preoperative to postoperative values within the intravenous group (from 12.00 to 10.60 gm%) was not statistically significant (t = 1.85, p = 0.080). Likewise, the drop within the topical group (from 11.85 to 10.40 gm%) was not statistically significant (t= 1.92, p = 0.070). These values suggest that both groups experienced comparable hemoglobin reductions, likely due to intraoperative blood loss and perioperative fluid shifts, but without reaching statistical significance. Further, in the intergroup comparison of haemoglobin drop, the mean haemoglobin drop was 1.40 ± 0.50 gm% in the intravenous group and 1.45 ± 0.60 gm% in the topical group. This difference was not statistically significant (t = -0.30, p = 0.760), indicating that both administration routes offered similar efficacy in blood conservation.

These findings are consistent with existing literature. For example, a meta-analysis by Hui S et al [6] showed only a marginal hemoglobin drop difference (0.05 g/dL) favoring topical TXA over placebo, but no significant difference between topical and intravenous routes. Similarly, Mu X et al [1] reported higher postoperative hemoglobin and hematocrit levels in both TXA groups compared to placebo, without significant differences between IV and topical routes. In addition, Luo W et al [21] reported significantly better hemoglobin preservation in TXA-treated patients compared to controls (MD = 0.95, 95% CI: 0.44 to 1.47, p = 0.0003), further supporting the hemostatic benefit of TXA use. On the other hand, a study by Kitaguchi K et al [24] observed that topical TXA led to significantly lower perioperative blood loss and superior hemoglobin preservation compared to both IV TXA and control groups. However, such a difference was not evident in the present study, likely due to variations in surgical technique, TXA dosing, and patient characteristics.

Importantly, no thromboembolic events or other complications were observed in either group, reinforcing the safety profile of both intravenous and topical TXA in lumbar spine fusion surgery. In the present study, the topical group had a longer median hospital stay of 10 days and a mean of 8.95 days (SD = 3.28), whereas the intravenous group had a median of 5 days and a mean of 7.4 days (SD = 3.21). The t-value was 1.5 and the p-value was 0.139, suggesting that while the topical group stayed longer on average, the difference was not statistically significant. Another alike study by Hui S et al [6] found that topical Tranexamic Acid (tTXA) was associated with a weighted mean difference (WMD) of -1.32 days (95% CI: -1.90 to -0.74; p < 0.00001) in length of hospital stay and concluded that tTXA use in spinal surgeries significantly reduces hospital stay duration. In line with our study, Mu X et al [1] found that both the

intravenous TXA group and the topical TXA group had significantly lower length of hospital stay than the placebo group. In a meta-analysis by Luo W et al [69], the efficacy and safety of tranexamic acid (TXA) in spine surgery was evaluated and the results showed significant differences in length of hospital stay (MD = -1.42, 95% CI -1.92 to -0.93, P< 0.00001) as compare to control group in which no tranexamic acid was applied.

There are few studies have directly compared the efficacy of intravenous and topical TXA administration in spinal surgery. Our study is an attempt to fill this gap in the literature by comparing the efficacy of intravenous versus topical TXA administration in reducing postoperative drain output in lumbar spine fusion surgery. We found that both intravenous and topical TXA were effective in reducing postoperative blood loss, with no significant difference between the two groups. Our study adds to the existing literature by providing a direct comparison of the two administration routes, which can guide future research. The results of our study are consistent with previous studies that have shown the efficacy and safety of TXA in reducing blood loss and transfusion requirements in spinal surgery.

CONCLUSION

The comparative analysis of intravenous and topical tranexamic acid in lumbar spine fusion surgery suggests that both routes are effective and safe for minimizing postoperative blood loss, without significant differences in drain output, hemoglobin drop, or hospital stay. While intravenous tranexamic acid showed a trend toward reduced drain output, topical application remains a promising alternative, particularly in patients at risk of systemic complications from intravenous use. Larger randomized controlled trials with extended follow-up are warranted to establish definitive recommendations for the optimal route of tranexamic acid administration in spine surgery.

REFERENCES

1. Mu X, Wei J, Wang C, Ou Y, Yin D, Liang B, Qiu D, Li Z. Intravenous administration of tranexamic acid significantly reduces visible and hidden blood loss compared with its topical administration for double-segment posterior lumbar interbody fusion: a single-center, placebo-controlled, randomized trial. World neurosurgery. 2019 Feb 1;122:e821-7.
2. Yerneni K, Burke JF, Tuchman A, Li XJ, Metz LN, Lehman Jr RA, Lenke LG, Tan LA. Topical tranexamic acid in spinal surgery: a systematic review and meta-analysis. Journal of Clinical Neuroscience. 2019 Mar 1;61:114-9.
3. Lin JD, Lenke LG, Shillingford JN, Laratta JL, Tan LA, Fischer CR, Weller MA, Lehman Jr RA. Safety of a high-dose tranexamic acid protocol in complex adult spinal deformity: analysis of 100 consecutive cases. Spine deformity. 2018 Mar 1;6(2):189-94.
4. Xiong Z, Liu J, Yi P, Wang H, Tan M. Comparison of Intravenous versus Topical

Tranexamic Acid in Nondeformity Spine Surgery: A Meta-Analysis. BioMed Research International. 2020;2020(1):7403034.

5. Gill JB, Chin Y, Levin A, Feng D. The use of antifibrinolytic agents in spine surgery: a meta-analysis. JBJS. 2008 Nov 1;90(11):2399-407.
6. Hui S, Xu D, Ren Z, Chen X, Sheng L, Zhuang Q, Li S. Can tranexamic acid conserve blood and save operative time in spinal surgeries? A meta-analysis. The Spine Journal. 2018 Aug 1;18(8):1325-37.
7. Ren Z, Li S, Sheng L, Zhuang Q, Li Z, Xu D, Chen X, Jiang P, Zhang X. Topical use of tranexamic acid can effectively decrease hidden blood loss during posterior lumbar spinal fusion surgery: a retrospective study. Medicine. 2017 Oct 1;96(42):e8233.
8. Hourlier H, Reina N, Fennema P. Single dose intravenous tranexamic acid as effective as continuous infusion in primary total knee arthroplasty: a randomised clinical trial. Arch Orthop Trauma Surg. 2015;135(4):465-471.
9. Ohashi N, Ohashi M, Endo N, Kohno T. Administration of tranexamic acid to patients undergoing surgery for adolescent idiopathic scoliosis evokes pain and increases the infusion rate of remifentanil during the surgery. PLoS One. 2017;12(12):e0189087.
10. 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.
11. Wang S, Gao X, An Y. Topical versus intravenous tranexamic acid in total knee arthroplasty: a meta-analysis of randomized controlled trials. Int Orthop. 2017;41(4):739-748.
12. Winter SF, Santaguida C, Wong J, Fehlings MG. Systemic and topical use of tranexamic acid in spinal surgery: a systematic review. Glob Spine J. 2016;6(3):284-295.
13. Lecker I, Wang DS, Whissell PD, Avramescu S, Mazer CD, Orser BA. Tranexamic acid–associated seizures: causes and treatment. Ann Neurol. 2016;79(1):18-26.
14. Ker K, Edwards P, Perel P, Shakur H, Roberts I. Effect of tranexamic acid on surgical bleeding: systematic review and cumulative meta-analysis. BMJ. 2012;344:e3054.
15. Takagi H, Ando T, Umemoto T. All-Literature Investigation of Cardiovascular Evidence (ALICE) group. Seizures associated with tranexamic acid for cardiac surgery: a meta-analysis of randomized and non-randomized studies. J Cardiovasc Surg. 2017;58(4):633–41.
16. Lin Z, Xiaoyi Z. Tranexamic acid-associated seizures: a meta-analysis. Seizure. 2016;36:70–3.
17. Couture P, Lebon JS, Laliberté É, Desjardins G, Chamberland MÈ, Ayoub C, et al. Low-dose versus high-dose tranexamic acid reduces the risk of nonischemic

seizures after cardiac surgery with cardiopulmonary bypass. J Cardiothorac Vasc Anesth. 2017;31(5):1611–7.

18. Patel JN, Spanyer JM, Smith LS, Huang J, Yakkanti MR, Malkani AL. Comparison of intravenous versus topical tranexamic acid in total knee arthroplasty: a prospective randomized study. J Arthroplast. 2014;29(8):1528–31.
19. Chang CH, Chang Y, Chen DW, Ueng SW, Lee MS. Topical tranexamic acid reduces blood loss and transfusion rates associated with primary total hip arthroplasty. Clin Orthop Relat Res. 2014;472(5):1552–7.
20. Gilbody J, Dhotar HS, Perruccio AV, Davey JR. Topical tranexamic acid reduces transfusion rates in total hip and knee arthroplasty. J Arthroplast. 2014;29(4):681–4.
21. Luo W, Sun RX, Jiang H, Ma XL. The efficacy and safety of topical administration of tranexamic acid in spine surgery: a meta-analysis. Journal of orthopaedic surgery and research. 2018 Apr 24;13(1):96.
22. Krohn CD, Sørensen R, Lange JE, Riise R, Bjørnsen S, Brosstad F. Tranexamic acid given into the wound reduces postoperative blood loss by half in major orthopaedic surgery. Eur J Surg Suppl. 2003 Jul;(588):57-61.
23. Dunn CJ, Goa KL. Tranexamic acid: a review of its use in surgery and other indications. Drugs. 1999 Jun;57(6):1005-32.
24. Kitaguchi K, Kaito T, Wada E. 64. Comparison of the effects of topical and intravenous administration of tranexamic acid on postoperative blood loss in single-level posterior lumbar interbody fusion. North American Spine Society Journal (NASSJ). 2024 Jul 1;18:100402.