Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Combined Intravenous and Topical Tranexamic Acid for Blood Loss and Enhanced Recovery After Total Hip Arthroplasty: A Three-Arm Randomized Trial

Wei Tao
First Hospital of Jilin University
Yuhang Wang
First Hospital of Jilin University
Yu Han
First Hospital of Jilin University
Wei Feng
First Hospital of Jilin University
Dongsong Li
First Hospital of Jilin University
Junting Zang
zjtinglt@jlu.edu.cn

First Hospital of Jilin University

Research Article

Keywords: Total Hip Arthroplasty, Tranexamic Acid, Topical Administration, Blood Loss, Enhanced Recovery After Surgery

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11314564/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

This study evaluated different topical tranexamic acid (TXA) administration routes combined with intravenous (IV) TXA for perioperative blood loss and enhanced recovery after total hip arthroplasty (THA).

Methods

In this prospective, patient- and assessor-blinded randomized controlled trial, 96 patients undergoing THA were randomized to three groups (n = 32 each); all received IV TXA 1.0 g 15 minutes before incision. The PAI group received periarticular injection (PAI) (TXA 1.0 g/10 mL) before closure; the combined group received PAI (0.5 g/5 mL) plus intra-articular injection (IAI) (0.5 g/5 mL); the control group received IAI (TXA 1.0 g/10 mL). The primary outcome was total blood loss; secondary outcomes included hidden blood loss, maximum hemoglobin drop, length of hospital stay, time to first ambulation, transfusion rate, Harris Hip Score (HHS), Goodman Satisfaction Score, and inflammatory markers.

Results

Total blood loss was significantly lower in the PAI group (1,180.44 ± 440.83 mL) and the combined group (1,085.19 ± 353.84 mL) than in the control group (1,549.83 ± 503.66 mL) ($P < 0.01$), with concordant trends in hidden blood loss and maximum hemoglobin drop. The combined group showed enhanced recovery after surgery (ERAS) benefits, with earlier first ambulation (2.92 vs. 3.28 and 3.18 hours) and shorter hospital stay (4.62 vs. 5.72 and 5.87 days) ($P < 0.05$). Inflammatory markers, HHS, Goodman Satisfaction Score, transfusion rates, and adverse events did not differ significantly among groups ($P > 0.05$).

Conclusions

Combined IV, PAI, and IAI TXA can reduce blood loss, shorten hospital stay, and promote early ambulation without increasing complications.

Trial registration

Chinese Clinical Trial Registry, ChiCTR2600128882. Registered retrospectively (July 2026).

Background

Total hip arthroplasty (THA) is an effective treatment for end-stage hip diseases, including osteonecrosis of the femoral head, osteoarthritis, and developmental dysplasia of the hip [1]. However, THA is frequently associated with substantial perioperative blood loss, with postoperative transfusion rates ranging from 10% to 22% [2]. Controlling perioperative blood loss reduces transfusion requirements and minimizes risks such

as infection, immunological reactions, and transfusion-related acute lung injury, while promoting early functional recovery and shortening hospital stay [3]. Thus, reducing perioperative blood loss and transfusion requirements remains an important focus in joint surgery.

Combined intravenous (IV) and topical administration of tranexamic acid (TXA) represents the mainstream hemostatic strategy in perioperative joint arthroplasty [4, 5]. However, existing studies have predominantly focused on combined versus single-route administration or comparisons between single routes, with limited evidence directly comparing the hemostatic efficacy of different topical administration routes [6, 7]. A meta-analysis by Shang et al. demonstrated that combined IV and topical TXA was superior to IV TXA alone in total blood loss, hemoglobin drop, transfusion requirements, and length of hospital stay in primary total knee and hip arthroplasty [8]. Anatomically, the hip is enveloped by abundant muscle tissue, and deep perioperative bleeding arises from the capsular margin and external rotator muscle insertion [9]; optimizing the topical TXA route may enhance hemostasis [6]. Therefore, the primary hypothesis of this study was that combined IV TXA with periarticular injection (PAI) and intra-articular injection (IAI) would achieve superior hemostatic efficacy compared with IV TXA combined with PAI alone or IAI alone.

The enhanced recovery after surgery (ERAS) concept emphasizes optimizing perioperative interventions to reduce physiological and psychological stress and accelerate postoperative recovery [10]. Perioperative blood loss exacerbates surgical stress and postoperative anemia and increases the risk of infection, thromboembolic events, and allogeneic transfusion, ultimately prolonging hospital stay and delaying functional recovery [11]. Thus, effective perioperative blood management in THA is critical for advancing ERAS. However, despite the widespread adoption of combined IV and topical TXA, the optimal topical administration route—PAI, IAI, or their combination—has not been established, and prior studies have predominantly focused on blood loss endpoints without systematically evaluating ERAS outcomes or integrating pharmacokinetic evidence. To address this gap, the present study is, to the best of our knowledge, the first three-arm randomized controlled trial in THA to directly compare PAI, IAI, and combined PAI + IAI under a fixed IV TXA background, incorporating ERAS endpoints (length of hospital stay and time to first ambulation) and integrating pharmacokinetic/pharmacodynamic (PK/PD) evidence for mechanistic interpretation. The secondary hypothesis of this study was that combined IV TXA with PAI and IAI could accelerate postoperative recovery in patients undergoing THA.

Materials and Methods

1.1 General Information

This prospective, patient- and assessor-blinded randomized controlled trial was approved by the Ethics Committee of the First Hospital of Jilin University (approval number: 26K230-001), registered in the Chinese Clinical Trial Registry (ChiCTR2600128882), and all patients provided written informed consent. Between January and June 2026, 134 patients scheduled for primary unilateral THA at a single tertiary care center were assessed for eligibility; 33 were ineligible, 4 declined, and 1 was excluded for other reasons. Ultimately, 96 patients (62 men and 34 women; 46 left-sided and 50 right-sided hips) were randomized and all

completed the study; baseline characteristics were comparable among the three groups (Table 1). The study flow is shown in Fig. 1.

Table 1
Baseline characteristics of the patients.

Variable	PAI group	Combined group	Control group	Statistic	*P* value
Age (years)	54.91 ± 10.57	54.59 ± 9.01	55.50 ± 11.16	$F = 0.064$	0.938
Surgical Side (left/right)	17/15	15/17	14/18	$\chi^2=0.584$	0.747
Sex (Men/Women)	20/12	17/15	25/7	$\chi^2=4.463$	0.107
BMI (kg/m²)	25.78 ± 3.40	24.92 ± 4.30	25.35 ± 3.89	$F = 0.393$	0.676
PT (s)	11.40(10.53,11.78)	11.05(10.63,11.68)	11.15(10.50,11.90)	$H = 0.328$	0.849
APTT (s)	27.28 ± 2.60	27.27 ± 2.20	26.90 ± 2.67	$F = 0.243$	0.785
TT (s)	18.15(17.48,18.60)	17.55(17.10,17.55)	17.90(17.23,18.83)	$H = 3.667$	0.160
FBG (g/L)	2.89(2.45,3.45)	2.70(2.38,3.27)	2.69(2.46,3.36)	$H = 0.631$	0.729
Preoperative TBV (mL)	4,371.41 ± 707.81	4,246.57 ± 741.07	4,566.84 ± 717.44	$F = 1.599$	0.208
Preoperative CRP (mg/L)	3.13 ± 1.52	2.85 ± 1.91	2.91 ± 1.94	$F = 0.217$	0.805
Preoperative ESR (mm/h)	14.50(9.00,28.25)	18.50(12.00,24.00)	10.00(8.00,21.00)	$H = 3.252$	0.197
Operative Time (min)	80.06 ± 16.83	80.94 ± 11.85	84.44 ± 14.67	$F = 0.805$	0.450

Data are presented as mean ± SD for normally distributed variables, and median (IQR) for non-normally distributed variables. *H*, Kruskal-Wallis test; *F*, one-way ANOVA; χ^2, *chi-square* test.

Abbreviations: BMI, body mass index; PT, prothrombin time; APTT, activated partial thromboplastin time; TT, thrombin time; FBG, fibrinogen; TBV, total blood volume; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; SD, standard deviation; IQR, interquartile range

1.1.1 Inclusion Criteria

(1) Adults aged ≥ 18 years with a body mass index (BMI) of 18–35 kg/m² (inclusive).

(2) Definite diagnosis of unilateral or bilateral primary hip osteoarthritis, osteonecrosis of the femoral head, or developmental dysplasia of the hip meeting surgical indications.

(3) Preoperative white blood cell count, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and coagulation parameters (prothrombin time [PT], activated partial thromboplastin time [APTT], thrombin time [TT], plasma fibrinogen [FBG]) all within normal ranges.

1.1.2 Exclusion Criteria

(1) History of thromboembolic events, coagulation disorders, cardiovascular or renal disease, pregnancy, lactation, hematuria, TXA allergy, or other contraindications.

(2) Substantial comorbidities classified as American Society of Anesthesiologists (ASA) class IV or V [12], dementia, or inability to comply with study instructions.

- (3) Receipt of fresh frozen plasma, other blood products, or anticoagulant derivatives within 24 hours preoperatively.

(4) Previous hip surgery (internal fixation, hip arthroscopy, revision arthroplasty, etc.) or prior osteotomy for hip dysplasia.

(5) Confirmed coagulopathy (e.g., hemophilia, von Willebrand disease), thrombocytopenia (< 100 × 10^9/L), or anticoagulant/antiplatelet therapy that could not be discontinued per protocol.

1.2 Interventions

1.2.1 Randomization and Blinding

Patients and outcome assessors were blinded. A block randomization sequence with mixed block sizes of 6 and 9 allocated the three groups equally within each block.

After written informed consent, the custodian retrieved the next sequentially numbered sealed envelope and handed it to the circulating nurse. Following anesthesia induction, the circulating nurse and medication physician opened the envelope together, confirmed the allocation, and administered TXA per protocol.

1.2.2 Surgical Procedure

All patients received TXA 1.0 g in 100 mL normal saline intravenously 15 minutes before incision. All procedures were performed by the same surgical team via the posterolateral approach under general anesthesia. Topical TXA (1.0 g/10 mL) was administered as follows: PAI group—full dose injected into the capsular margin and external rotator muscle insertion before closure; combined group—5 mL injected into these sites before closure and 5 mL into the intra-articular space after capsular closure; control group—full dose injected into the intra-articular space after capsular closure.

1.2.3 Study Flowchart

[Insert Fig. 1 here]

1.2.4 Postoperative Management

Postoperative care followed the Chinese expert consensus on ERAS for hip and knee arthroplasty [13], including fluid resuscitation, infection prophylaxis, analgesia, gastrointestinal protection, and edema management. Ice packs were applied to the incision; after 72 hours, local heat therapy was initiated.

Oral rivaroxaban (10 mg once daily) was started 6 hours postoperatively; prophylactic antibiotics were given within 24 hours. Patients performed immediate active hip, knee, and ankle flexion-extension exercises and straight leg raises. Complete blood count, CRP, and ESR were measured daily at 8:00 AM.

Transfusion was given when hemoglobin was < 70 g/L or 70–90 g/L with signs of acute anemia (tachycardia, weakness, dizziness, hypotension). At 1-month follow-up, Doppler ultrasound and chest CT were performed as indicated to screen for deep vein thrombosis and pulmonary embolism.

1.3 Outcome Measures

1.3.1 Primary Outcomes

- (1) Total Blood Loss: Preoperative total blood volume (TBV) was calculated using the Nadler
- equation [14] (Eq. (1)): TBV (mL) = 1,000 × ($K_1 \times H^3 + K_2 \times W + K_3$) (1) Where H is
- height (m), W is weight (kg), with K_1 = 0.3669, K_2 = 0.03219, and K_3 = 0.6041 for men, and
- K_1 = 0.3561, K_2 = 0.03308, and K_3 = 0.1833 for women.
- Total blood loss (TBL) was calculated using the Gross equation [15] (Eq. (2)): TBL (mL) = 1,000 × [TBV × ($Hctpreop - Hctpostlowest$) / Hct_V + $Vtransfusion$] (2) where Hct_V = ($Hctpreop$ + $Hctpostlowest$)/2, and $Hctpostlowest$ was the lowest hematocrit recorded from surgery to discharge.

1. Hidden Blood Loss (HBL) was calculated as total blood loss − intraoperative blood loss, as no drains were used and visible blood loss was limited to intraoperative suction and gauze loss.
2. Maximum Hemoglobin Drop (ΔHb) was calculated as ΔHb = Hbpreop − Hbpostlowest (within 5 days).
3. Intraoperative Blood Loss was defined as blood in suction canisters and weighed gauze sponges.

1.3.2 Secondary Outcomes

- (1) Length of Hospital Stay: days from surgery completion to discharge after meeting discharge criteria.

1. Time to First Ambulation: hours from return to the ward to first assisted standing and walking (at least one step).
2. Transfusion Rate: proportion of patients receiving allogeneic red blood cell transfusion during hospitalization.
3. Harris Hip Score (HHS): assessed preoperatively and at 1 month postoperatively.
4. Patient Satisfaction (Goodman score [16]): assessed at 1 month postoperatively.
5. Inflammatory Markers: ESR and CRP on postoperative days 1 and 3.
6. Adverse Events: wound healing status, cerebrovascular events, pulmonary embolism, and lower extremity deep vein thrombosis.

1.4 Data Analyses

The sample size was calculated using G*Power 3.1 (F tests - ANOVA: Fixed effects, omnibus, one-way). Based on previous studies [17, 18], a moderate-to-large effect size (Cohen's f = 0.333) was assumed. With a two-sided significance level of $\alpha = 0.05$ and a power ($1 - \beta$) of 0.80, to compensate for potential loss to follow-up and ensure adequate power, 32 patients per group (96 total) were enrolled, providing an actual power of 82.8%.

Analyses were performed using SPSS (version 27.0, IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test. Normally distributed data were expressed as mean ± SD and compared using one-way ANOVA, with *post hoc* least significant difference (LSD) tests; non-normally distributed data were expressed as median (IQR) and compared using the Kruskal-Wallis H test, with *post hoc* Dunn-Bonferroni comparisons (adjusted $\alpha = 0.0167$). Categorical variables were compared using the *chi-square* test, or Fisher's exact test when any expected frequency was < 5.

During the preparation of this work, the authors used artificial intelligence tools to assist with language polishing. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Results

2.1 Primary Outcomes

TBL, HBL, and ΔHb were significantly lower in the PAI and combined groups than in the control group ($P < 0.01$), with no significant difference between the PAI and combined groups ($P > 0.05$). Intraoperative blood loss did not differ significantly among groups ($P > 0.05$), as detailed in Table 2.

Table 2
Primary outcomes.

Variable	PAI group	Combined group	Control group	Statistic	*P* value
Total Blood Loss (mL)	1,180.44 ± 440.83	1,085.19 ± 353.84	1,549.83 ± 503.66	$F = 10.088$	< 0.01
Hidden Blood Loss (mL)	975.13 ± 409.74	894.57 ± 334.07	1,339.83 ± 507.15	$F = 10.069$	< 0.01
Intraoperative Blood Loss (mL)	205.31 ± 45.37	190.63 ± 39.59	210.00 ± 36.10	$F = 1.990$	0.142
Maximum Hemoglobin Drop (g/L)	30.72 ± 11.05	30.63 ± 9.70	40.05 ± 12.05	$F = 8.554$	< 0.01

Data are presented as mean ± SD. *F*, one-way ANOVA; SD, standard deviation.

2.2 Enhanced Recovery Outcomes

Length of hospital stay was significantly shorter in the combined group than in the PAI and control groups (Kruskal-Wallis test, $P = 0.002$; *post hoc* Dunn-Bonferroni, $P < 0.05$), without a significant difference between the PAI and control groups. Time to first ambulation was also significantly earlier in the combined group ($P < 0.05$; no significant difference between PAI and control, $P > 0.05$), as detailed in Table 3.

Table 3
Secondary outcomes.

Variable	PAI group	Combined group	Control group	Statistic	*P* value
CRP (POD 1, mg/L)	26.86(13.82,37.74)	33.36(11.92,49.88)	37.82(17.21,55.62)	*H* = 2.494	0.287
CRP (POD 3, mg/L)	64.04(23.48,89.57)	77.14(24.56,117.94)	77.47(35.37,121.27)	*H* = 1.780	0.411
ESR (POD 1, mm/h)	42.91 ± 24.17	36.28 ± 26.81	38.46 ± 24.30	*F* = 0.578	0.563
ESR (POD 3, mm/h)	46.84 ± 23.17	47.34 ± 25.18	46.13 ± 20.99	*F* = 0.022	0.978
Preoperative Harris Hip Score	49.53 ± 3.91	49.25 ± 3.50	48.97 ± 3.60	*F* = 0.188	0.829
Postoperative Harris Hip Score	84.94 ± 2.66	85.31 ± 2.91	85.00 ± 2.38	*F* = 0.182	0.834
Postoperative Goodman Satisfaction Score	89.22(85.00,90.00)	89.37(85.00,90.00)	90.63(90.00,95.00)	*H* = 2.878	0.237
Length of Stay (days)	5.72(5.00,6.00)	4.62(4.00,5.00)	5.87(5.00,6.00)	*H* = 12.344	0.002
Time to First Ambulation (h)	3.28 ± 0.55	2.92 ± 0.56	3.18 ± 0.52	*F* = 3.731	0.028
Transfusion, n (%)	2 (6.3)	1 (3.1)	2 (6.3)	χ^2=0.459	0.795
Data are presented as mean ± SD for normally distributed variables, and median (IQR) for non-normally distributed variables; *F*, one-way ANOVA; *H*, Kruskal-Wallis test; χ^2, *chi-square* test.					
Abbreviations: POD, postoperative day; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; HHS, Harris Hip Score; SD, standard deviation; IQR, interquartile range					

2.3 Other Secondary Outcomes

Transfusion was required in 2, 1, and 2 patients in the PAI, combined, and control groups, respectively ($P > 0.05$). No major adverse events occurred; only one isolated calf muscular vein thrombosis occurred in the control group. No significant differences were observed among the three groups in CRP or ESR on

postoperative days 1 and 3, or in preoperative HHS, postoperative HHS, or Goodman Satisfaction Score ($P > 0.05$), as detailed in Table 3.

Discussion

This prospective randomized controlled study compared the hemostatic efficacy and ERAS outcomes of different TXA topical administration routes in THA. Perioperative blood management substantially impacts patient recovery and long-term prognosis [3]. Although combined IV and topical administration of TXA has been widely adopted [4], consensus on the optimal topical administration route has not been reached, and different topical routes may exert distinct hemostatic effects.

The first finding was that total blood loss was (1,180.44 ± 440.83) mL in the PAI group and (1,085.19 ± 353.84) mL in the combined group, significantly lower than (1,549.83 ± 503.66) mL in the control group (IV + IAI) ($P < 0.01$). Gurunathan et al., using a PK/PD model in THA, demonstrated that a single IV bolus of TXA (15 mg/kg) maintained an effective antifibrinolytic concentration of 10 mg/L for a median duration of only 4.94 hours, leaving most of the 24-hour postoperative period below the effective concentration, suggesting that IV TXA alone cannot achieve sustained coverage throughout the period of persistent postoperative bleeding in THA [19]. Although conducted in total knee arthroplasty (TKA), the study by Pinsornsak et al. directly compared the systemic absorption differences between PAI and IAI, finding that the postoperative 2-hour serum TXA concentration in the PAI group (15.6 mg/L) was significantly lower than that in the IAI group (28.2 mg/L, $P < 0.01$) [20]. This provides mechanistic insight into the pharmacokinetic profiles of different topical administration routes: TXA administered via PAI is primarily retained in local soft tissues with less systemic absorption and a longer duration of action, whereas TXA administered via IAI is more readily absorbed into the systemic circulation via the synovium, resulting in higher systemic exposure. Based on these pharmacokinetic observations, the combined group in the present study divided 1.0 g of TXA into 0.5 g via PAI and 0.5 g via IAI, maintaining the same total dose as the PAI and control groups. This may be explained by the fact that the sustained retention of PAI-administered TXA in local soft tissues fills the subtherapeutic concentration gap after IV administration, while IAI controls intra-articular bleeding, achieving multi-level control of persistent postoperative bleeding after THA and thereby exerting synergistic hemostatic effects superior to those of single-route topical administration.

A second finding was that the intergroup trends in hidden blood loss ($P < 0.01$) and maximum hemoglobin drop ($P < 0.01$) were consistent with those of total blood loss, indicating that hidden blood loss is the predominant component of total blood loss after THA. Sun et al., in a study of 505 THA patients, reported that hidden blood loss (911 ± 438 mL) accounted for 79.5% of total blood loss (1,104 ± 468 mL), suggesting that hidden blood loss is a key determinant of postoperative hemoglobin decline and total blood loss [21]. In the present study, intraoperative blood loss showed no significant difference among the three groups ($P = 0.142$), ruling out differences in surgical technique as major confounders. Thus, the differences in hemostatic efficacy among the three groups were primarily attributable to the control of persistent postoperative bleeding from soft tissue interstitial spaces after wound closure through different topical administration routes.

A third finding of this study was that postoperative hospital stay in the combined group (4.62 (4.00, 5.00) days) was significantly shorter than that in the PAI group (5.72 (5.00, 6.00) days) and the control group (5.87 (5.00, 6.00) days) *(P = 0.002)*, and time to first ambulation in the combined group (2.92 ± 0.56 hours) was also significantly earlier than that in the PAI group (3.28 ± 0.55 hours) and the control group (3.18 ± 0.52 hours) *(P = 0.028)*. Previous studies have confirmed that the incidence of postoperative anemia after THA can be as high as 51% [22], and that postoperative anemia is an important factor affecting early mobilization and functional recovery [23]. The present results demonstrate that although the PAI and combined groups had comparable hemostatic efficacy (no statistically significant difference), the combined group may have more effectively reduced postoperative intra-articular hematoma by simultaneously covering both soft tissue bleeding points and intra-articular bleeding surfaces, thereby providing patients with more favorable conditions for early mobilization. Given that blood loss and maximum hemoglobin drop were comparable between the PAI and combined groups, the earlier ambulation in the combined group may be attributable to more effective control of intra-articular bleeding rather than a greater reduction in blood loss. However, because intra-articular hematoma was not directly measured in this study, this proposed mechanism remains speculative and requires further investigation.

A fourth finding was that no significant differences were observed among the three groups in CRP or ESR on postoperative days 1 and 3 *(P > 0.05)*, suggesting that different topical administration routes did not produce additional systemic inflammatory effects beyond the unified IV regimen. No significant differences were found in postoperative HHS or Goodman Satisfaction Scores *(P > 0.05)*, which may be attributable to the short follow-up period, as the 1-month time point may be too early to detect differential recovery among groups [24]. Transfusion rates and adverse event rates, including thromboembolic events, showed no significant differences among the three groups *(P > 0.05)*, indicating a favorable safety profile for the combined regimen.

This study had several limitations. The single-center design and sample size, calculated based on the primary endpoint of total blood loss, limited detection to moderate or larger effect sizes; small clinical differences and rare safety events may not have been detected, and the conclusions require validation through multicenter, large-sample studies. Follow-up was primarily focused on short-term perioperative indicators, and postoperative functional scores were only assessed up to 1 month; long-term outcomes such as joint function at 3 to 6 months and 1 year, as well as heterotopic ossification, were not systematically evaluated.

Conclusions

In conclusion, adding PAI and IAI to IV TXA reduces perioperative blood loss in THA, with additional advantages in shortening length of hospital stay and facilitating early ambulation, without increasing the risk of systemic inflammation, thrombosis, or wound complications. Therefore, the authors recommend combined IV, periarticular, and intra-articular injection as the preferred topical TXA regimen for perioperative hemostasis and enhanced recovery in THA.

Abbreviations

ASA
American Society of Anesthesiologists
ΔHb
maximum hemoglobin drop
FBG
plasma fibrinogen
IV
intravenous
LSD
least significant difference
PK/PD
pharmacokinetic/pharmacodynamic
TBL
total blood loss
TKA
total knee arthroplasty
APTT
activated partial thromboplastin time
BMI
body mass index
CRP
C-reactive protein
ERAS
enhanced recovery after surgery
ESR
erythrocyte sedimentation rate
HBL
hidden blood loss
HHS
Harris Hip Score
IAI
intra-articular injection
IQR
interquartile range
PAI
periarticular injection
PT
prothrombin time
SD
standard deviation
TBV
total blood volume

THA
total hip arthroplasty
TT
thrombin time
TXA
tranexamic acid.

Declarations

Ethics approval and consent to participate

This prospective, patient- and assessor-blinded randomized controlled trial was approved by the Ethics Committee of the First Hospital of Jilin University (approval number: 26K230-001). All patients provided written informed consent. The trial was registered in the Chinese Clinical Trial Registry (ChiCTR2600128882).

Consent for publication

Not applicable.

Funding

This work was supported by the Clinical Research Special Fund of Zhongguancun Precision Medicine Foundation (Grant No. 2026J2YX3078). The authors also acknowledge the support from the Xinjiang Uygur Autonomous Region Health Care Research Special Project (Grant No. BL202462) for preliminary research of this study. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author Contribution

W.T. and J.Z. conceived and designed the study. W.T. wrote the main manuscript text and curated the data. Y.W. collected the data and conducted the investigation. Y.H. performed the formal analysis and validated the results. W.F. contributed to the methodology and resources. D.L. and J.Z. supervised and administered the project. J.Z. reviewed and edited the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgement

The authors are grateful to the participants for their participation in this study.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to patient privacy restrictions, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

References

1. **Roren A, Lefèvre-Colau M, Nguyen C. Total hip replacement or resistance training for severe hip osteoarthritis. N Engl J Med. 2025;392(2):205.**
2. **Buddhiraju A, Shimizu MR, Subih MA, Chen TLW, Seo HH, Kwon YM. Validation of machine learning model performance in predicting blood transfusion after primary and revision total hip arthroplasty. J Arthroplasty. 2023;38(10):1959–66.**
3. **Everhart JS, Sojka JH, Mayerson JL, Glassman AH, Scharschmidt TJ. Perioperative allogeneic red blood-cell transfusion associated with surgical site infection after total hip and knee arthroplasty. J Bone Joint Surg Am. 2018;100(4):288–94.**
4. **Zhou Z, Huang Z, Yang H, Weng X, Li T, Wang G, et al. Expert consensus on perioperative tranexamic acid and anticoagulant application for enhanced recovery after orthopaedic surgery in China. Chin J Bone Joint Surg. 2019;12(2):81–8.**
5. **Fillingham YA, Ramkumar DB, Jevsevar DS, Yates AJ, Bini SA, Clarke HD, et al. Tranexamic acid use in total joint arthroplasty: the clinical practice guidelines endorsed by the American Association of Hip and Knee Surgeons, American Society of Regional Anesthesia and Pain Medicine, American Academy of Orthopaedic Surgeons, Hip Society, and Knee Society. J Arthroplasty. 2018;33(10):3065–9.**
6. **Boucher M, Tremblay J, Pelet T, Dartus J, Belzile EL, Pelet S. Topical versus systemic tranexamic acid to reduce blood loss after total knee and total hip arthroplasty: a systematic review and meta-analysis. J Bone Joint Surg Am. 2025;107(20):2300–9.**
7. **Hsu L-I, Chen J-W, Hsu H-W, Hou S-M. Evaluating three routes of tranexamic acid administration in total hip and knee arthroplasty: a nationwide database analysis in Taiwan. Anesthesiology. 2026 [Epub ahead of print].**
8. **Shang J, Wang H, Zheng B, Rui M, Wang Y. Combined intravenous and topical tranexamic acid versus intravenous use alone in primary total knee and hip arthroplasty: a meta-analysis of randomized controlled trials. Int J Surg. 2016;36(Pt A):324–9.**
9. **Su H, Yu S, Huang H, Lin S, Zhou H, Chen L, et al. Importance of hip capsular repair in total hip arthroplasty (THA) via the posterior lateral approach: a five-year retrospective cohort study. Int Orthop. 2024;48(10):2567–77.**
10. **Chinese Expert Group on Enhanced Recovery After Surgery. Expert consensus on perioperative management of enhanced recovery after surgery in China (2016). Chin J Surg. 2016;54(6):413–8.**
11. **Friedman R, Homering M, Holberg G, Berkowitz SD. Allogeneic blood transfusions and postoperative infections after total hip or knee arthroplasty. J Bone Joint Surg Am. 2014;96(4):272–8.**

12. Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status-historical perspectives and modern developments. Anaesthesia. 2019;74(3):373–9.
13. Zhou Z, Weng X, Qu T, Zhang X, Yan S, Cao L, et al. Expert consensus on perioperative management strategies for enhanced recovery after hip and knee arthroplasty in China. Chin J Bone Joint Surg. 2016;9(1):1–9.
14. Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. Surgery. 1962;51(2):224–32.
15. Gross JB. Estimating allowable blood loss: corrected for dilution. Anesthesiology. 1983;58(3):277–80.
16. Goodman SM, Mehta BY, Kahlenberg CA, Krell EC, Nguyen J, Finik J, et al. Assessment of a satisfaction measure for use after primary total joint arthroplasty. J Arthroplasty. 2020;35(7):1792–9.
17. Yuan G, Xiao Y, Li Z, Chen Z, Liu X. Impact of surgical approaches on stem position and hidden blood loss in total hip arthroplasty: minimally invasive vs posterolateral. BMC Musculoskelet Disord. 2024;25(1):681.
18. Shen L, Jiang Z, Wang Q, Xu W. Topical use of tranexamic acid can reduce opioid consumption compared with intravenous use for patients undergoing primary total hip arthroplasty: a prospective randomized controlled trial. BMC Musculoskelet Disord. 2023;24(1):455.
19. Gurunathan U, Medcalf RL, Chiang L, Liu Z, Liu X, Keragala CB, et al. A pharmacokinetic/pharmacodynamic analysis of intravenous tranexamic acid in adult patients undergoing elective total hip arthroplasty (ORACLE). Br J Anaesth. 2026;136(4):1157–65.
20. Pinsornsak P, Phunphakchit J, Boontanapibul K. Efficacy and systemic absorption of peri-articular versus intra-articular administration of tranexamic acid in total knee arthroplasty: a prospective randomized controlled trial. Arthroplast Today. 2021;11:1–5.
21. Sun Y, Miao H, Gong H, Zhang Y, Hong W. Risk factors analysis and nomogram model establishment of hidden blood loss in overweight and obese elderly patients after total hip arthroplasty. Clin Interv Aging. 2024;19:57–66.
22. Spahn DR. Anemia and patient blood management in hip and knee surgery: a systematic review of the literature. Anesthesiology. 2010;113(2):482–95.
23. Minoda Y, Ohyama Y, Masuda S, Ueyama H, Sugama R, Terai H et al. Reducing postoperative anemia and enhancing postoperative recovery in TKA: exploring the synergistic effects of tranexamic acid and absorbable hemostat: commentary on an article by Qing-Yi Zhang, MD,. : Efficacy and Safety of Tranexamic Acid Combined with Absorbable Hemostat in Reducing Perioperative Blood Loss in Total Knee Arthroplasty. A Prospective, Blinded, Randomized Controlled Trial. J Bone Joint Surg Am. 2025;107(19):e94.
24. Sato EH, Stevenson KL, Blackburn BE, Peters CL, Archibeck MJ, Pelt CE, et al. Recovery curves for patient reported outcomes and physical function after total hip arthroplasty. J Arthroplasty. 2023;38(7S):S65–71.

Figures

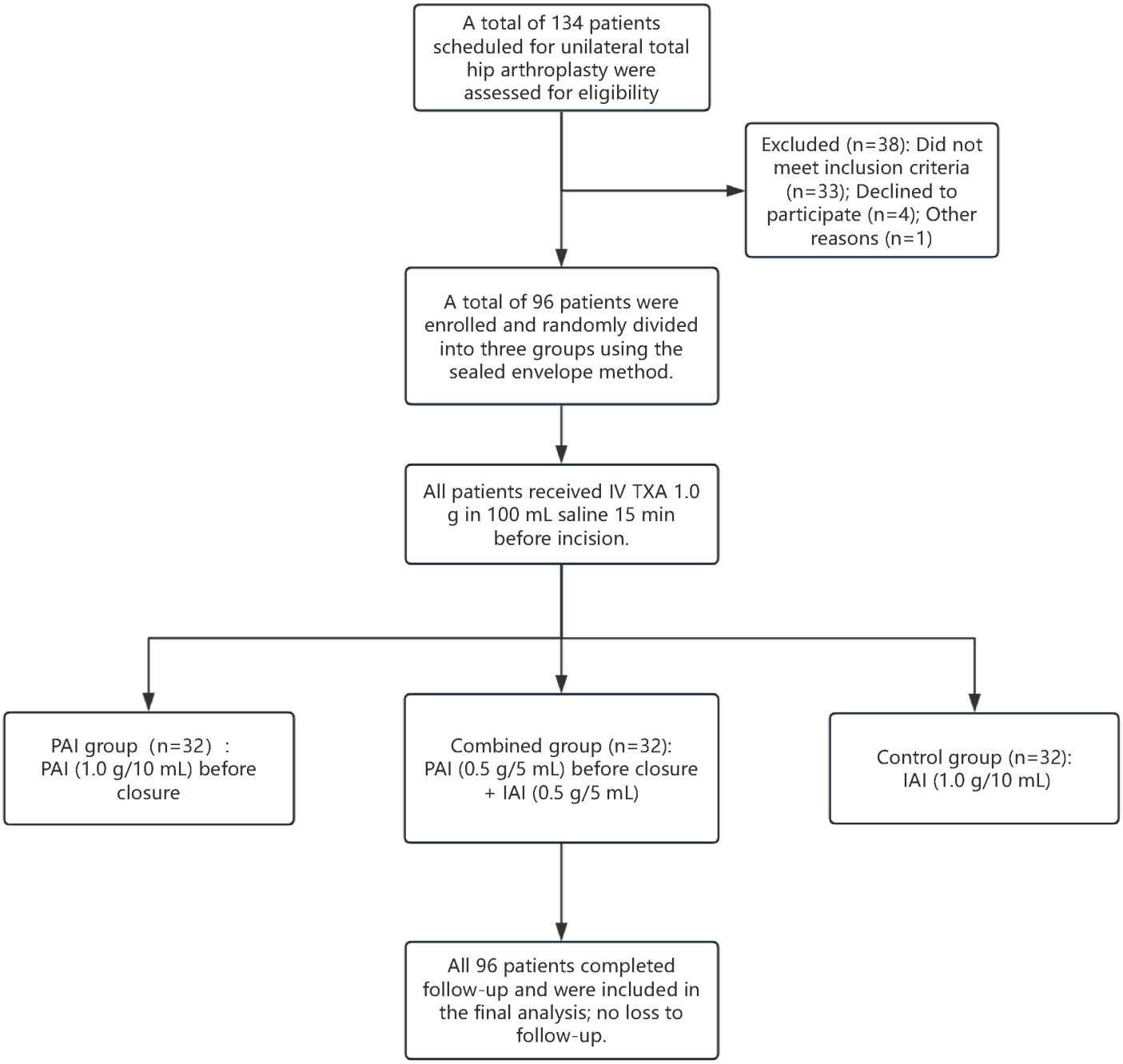


Figure 1. CONSORT flow diagram illustrating participant screening, eligibility assessment, random assignment, interventions, follow-up, and analysis of this three-arm parallel-group randomized controlled trial. THA, total hip arthroplasty.

Figure 1

See image above for figure legend