# Anesthetic Effects and Safety of Remimazolam Tosilate in Elderly Patients With Hip Fractures: A Retrospective Cohort Study

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AIM: The aim of this study is to evaluate the anesthetic effectiveness and safety of remimazolam tosilate (RT) compared with propofol in elderly patients undergoing hip fracture surgery.

METHODS: This retrospective cohort study analyzed clinical data from patients aged ≥60 years who underwent hip fracture surgery between January 2023 and December 2024 at our center. Patients were divided into two groups based on the anesthetic administered: group remimazolam tosilate (RT) (n = 105) and group propofol (P) (n = 115). Anesthetic efficacy outcomes included the time from the start of induction to achieving a bispectral index (BIS) ≤60 and a Modified Observer's Assessment of Alertness/Sedation (MOAA/S) score ≤3, as well as the time from discontinuation of the anesthetic agent to extubation and discharge from the post-anesthesia care unit (PACU). Safety outcomes included assessments of hemodynamic stability and the incidence of adverse events.

RESULTS: Both groups achieved comparable sedation efficacy (BIS ≤60, MOAA/S ≤3). Group RT exhibited significantly shorter extubation times (7.04 ± 1.41 min *vs* 12.50 ± 1.76 min, $p < 0.001$) and PACU discharge times (25.20 ± 3.06 min *vs* 38.57 ± 4.30 min, $p < 0.001$). Intraoperative hemodynamic stability was better in the group RT ($p < 0.05$); however, the intraoperative use of vasopressors (e.g., phenylephrine, ephedrine) and atropine was comparable between the two groups ($p > 0.05$ for all). The incidence of injection pain was lower in the group RT (5.71% *vs* 13.91%, $p = 0.043$).

CONCLUSIONS: RT provides effective anesthesia with faster recovery and enhanced hemodynamic stability compared to propofol in elderly patients undergoing hip fracture surgery. Additionally, its lower incidence of injection pain further supports its safety, suggesting that RT is a promising alternative for anesthesia in this patient population.

**Keywords:** remimazolam tosilate; propofol; elderly patients; hip fractures; anesthesia safety

## Introduction

Hip fractures are common and severe injuries among elderly individuals, often requiring surgical intervention [1]. In elderly patients, anesthesia management is particularly crucial due to the high prevalence of multiple chronic diseases. These conditions require careful selection and dosing of anesthetic agents to ensure effective anesthesia while minimizing adverse effects. Propofol, a widely used anesthetic, remains a standard choice; however, its relatively long pharmacokinetic half-life and potential for prolonged postoperative sedation can present significant challenges in elderly patients; in this group, overdose has been associated with an increased risk of 30-day mortality [2,3]. Recent advancements in anesthesiology have highlighted remimazolam, a novel ultrashort-acting benzodiazepine. Remimazolam acts on gamma-aminobutyric acid type A (GABA(A)) receptors and undergoes rapid hydrolysis *in vivo*, resulting in minimal dependence on liver and kidney function for clearance; its metabolites are pharmacologically inactive [4], thereby reducing the risk of drug accumulation. Compared to traditional benzodiazepines, remimazolam tosilate (RT) exhibits faster metabolism and a shorter recovery time, while maintaining safety even at high doses or prolonged infusion; additionally, its effects can be rapidly reversed with flumazenil in cases of overdose [5].

Although clinical studies have demonstrated the effectiveness of RT in various short-duration surgeries [6,7], its application in anesthesia for elderly patients undergoing hip fracture surgery remains under-explored. Therefore, this study aims to assess the anesthetic efficacy and safety of RT in elderly patients undergoing hip fracture surgery, and to compare its performance with that of the conventional anesthetic agent, propofol. Through this comparative analysis, we aim to provide scientific evidence to optimize anesthesia regimens for elderly patients.

## Methods

### *Study Design*

This retrospective study gathered clinical data from elderly patients who underwent hip fracture surgery in our department between January 2023 and December 2024. The re-

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search received approval from the Ethics Committee of Luxian People's Hospital (Approval No. 20240016). This study adhered to the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants.

*Inclusion and Exclusion Criteria*

This study involved 220 elderly patients who underwent hip fracture surgery in our department. Of these, 105 patients received RT induction (group RT), while 115 patients received propofol induction (group propofol [P]). The inclusion criteria were as follows: (1) patients with hip fracture confirmed by X-ray or Computed Tomography (CT) imaging and meeting the surgical indications specified in the "Treatment of Geriatric Hip Fractures: Evidence Based Clinical Practice Guidelines" published by the American Academy of Orthopaedic Surgeons [8]; (2) patients aged ≥60 years; and (3) patients meeting American Society of Anesthesiologists (ASA) classification I–II. The exclusion criteria were: (1) patients with severe organ dysfunction; (2) patients with known allergies to benzodiazepines, opioids, propofol, or any of their components; (3) patients with a history of dependence on sedative or analgesic drugs; (4) patients with severe psychiatric disorders; and (5) patients with refusal to provide informed consent.

*Anesthesia Procedure*

Patients underwent an 8-hour fasting period from both solids and liquids prior to entering the operating room. Upon arrival, the anesthesia team confirmed each patient's identity and conducted a thorough health assessment, which included a review of allergy history, medical history, and current medications. Venous access was established, and standard monitoring equipment was applied, including electrocardiogram, noninvasive blood pressure (NIBP), heart rate (HR), respiratory rate (RR), bispectral index (BIS), and pulse oxygen saturation ($SpO_2$). If necessary, arterial blood pressure was monitored via radial artery puncture. Sedation induction was conducted according to group allocation. Patients in the group RT received intravenous RT (0.2–0.4 mg/kg) until loss of consciousness [9], while those in the group P received intravenous propofol (1.5–2 mg/kg). Doses were titrated according to clinical requirements. Drug infusion was carried out using standard infusion pumps. Both groups also received sufentanil (0.4 μg/kg) and cisatracurium (0.15 mg/kg) to complete anesthesia induction. After confirming the intubation conditions, endotracheal intubation was performed, and patients were connected to a ventilator in volume-controlled ventilation mode, with a tidal volume (VT) of 6–8 mL/kg, an inspiratory-to-expiratory ratio of 1:2, a RR of 10–16 breaths/min, and end-tidal carbon dioxide partial pressure ($P_{ET}CO_2$) maintained at 35–45 mmHg. During surgery, anesthesia was maintained with an infusion of RT (0.3–0.5 mg/kg/h) in the group RT or propofol (4–8 mg/kg/h) in the group P, alongside with remifentanil (0.1–0.25 μg/kg/min) for analgesia. BIS values were continuously monitored. Anesthesiologists adjusted the infusion rate of anesthetic drugs based on BIS values and clinical signs (e.g., patient movement, changes in vital signs, etc.) to maintain a BIS target range of 40–60, ensuring adequate anesthetic depth. Hemodynamic management was as follow: intravenous phenylephrine (0.5 mg) or ephedrine (6 mg) was administered if BP dropped below 20% of baseline; nicardipine (0.25 mg) was given if BP exceeded 20% of baseline; atropine (0.3 mg) or ephedrine (6 mg) was administered if HR fell below 60 bpm with hypotension or below 50 bpm for over 1 minute; and esmolol (20 mg) was given when HR exceeded 100 bpm. Five minutes before the end of surgery, the rates of drug infusion were reduced by 20% and subsequently discontinued. At the conclusion of the surgery, both groups received intravenous flumazenil (0.3 mg) to reverse anesthetic effects. Once fully awake, patients were transferred to the post-anesthesia care unit (PACU) for a 30-minute observation. If consciousness was not regained, additional flumazenil was administered as needed. Patients were discharged to the ward after stabilization of vital signs.

*Exposure and Outcome Variables*

The exposure variable in this study is the induction of RT. The outcome variables consist of both anesthetic effects and safety parameters. Anesthetic effect outcomes are defined as follows: (1) time from the start of induction to BIS ≤60; (2) time from the start of induction to a Modified Observer Assessment of Alertness/Sedation (MOAA/S) score ≤3; (3) time from drug discontinuation to extubation; and (4) time from drug discontinuation to discharge from the PACU. BIS, a processed electroencephalogram (EEG) measure, is used to assess the depth of anesthesia (BIS: 81–100, awake; 61–80, light to moderate sedation; 41–60, moderate to deep sedation; ≤40, deep sedation or unconscious state) [10]. The MOAA/S score is a scale for evaluating sedation or alertness levels based on the patient's responses to auditory and physical stimuli (MOAA/S: 5, prompt response to a name called in a normal tone; 4, slow response to a name called in a normal tone; 3, response only after a loud or repeated call; 2, response only to light prodding or shaking; 1, no reaction to gentle prodding or shaking; 0, no reaction to painful stimuli) [11].

Safety outcomes include: (1) mean arterial pressure (MAP) and HR measured at various time intervals (T0, prior to induction; T1, right after induction; T2, right after tracheal intubation; T3, one hour after the start of surgery; and T4, at the conclusion of surgery); and (2) the incidence of adverse events, including intraoperative hypotension, hypoxemia, injection pain, as well as postoperative dizziness, nausea, and vomiting. MAP is calculated as: diastolic blood pressure + (systolic blood pressure – diastolic blood pressure)/3. Hypotension is defined as a reduction in MAP of more than 20% from the baseline or a systolic blood pressure ≤80

mmHg. Hypoxemia is defined as a sustained decrease in $SpO_2$ <90% lasting more than 60 seconds [12].

*Statistical Analysis*

Data processing and analysis were conducted using R version 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria). The Shapiro-Wilk test was used to assess the distribution of continuous variable data. Continuous variables with a normal distribution are expressed as mean ± standard deviation (SD) and were analyzed using the *t*-test. For skewed continuous variables, data are reported as median (1st quartile, 3rd quartile) and were assessed using the Mann-Whitney U test. Categorical variables are shown as frequency (%) and were analyzed using either the chi-square test or Fisher's exact test, as appropriate. Comparisons of MAP and HR between groups at different time points was performed using repeated measures analysis of variance (ANOVA), with time as a within-subject factor and group as a between-subject factor. When significant main effects or interactions were found, post-hoc pairwise comparisons were conducted using the Least Significant Difference (LSD) test. All statistical tests were two-tailed, and a *p*-value of less than 0.05 was considered statistically significant.

## Results

*Baseline Characteristics*

Between January 2023 and December 2024, a total of 220 elderly patients who underwent hip fracture surgery were included in this study. Among them, 105 patients received induction with RT, while 115 patients received induction with propofol. The mean age of the cohort was 71.21 ± 4.42 years. The study population comprised 161 females (73.18%) and 59 males (26.82%). There were no significant differences between the two groups regarding sex, age, height, weight, BMI, hypertension, diabetes, coronary heart disease (CHD), ASA classification, type and side of hip fracture, surgical method, duration of surgery, or duration of anesthesia (Table 1).

*Anesthetic Effect Outcomes*

Neither group experienced sedation failure. No statistically significant differences were observed between groups in the time to achieve BIS ≤60 or the time to reach a MOAA/S score ≤3. The group RT had a significantly shorter extubation time compared to the group P (group RT: 7.04 ± 1.41 min *vs* group P: 12.50 ± 1.76 min; $p < 0.001$). Moreover, the group RT experienced a notably shorter PACU discharge time than the group P (group RT: 25.20 ± 3.06 min *vs* group P: 38.57 ± 4.30 min; $p < 0.001$) (Table 2).

*Safety Outcomes*

MAP changes over time and between the two groups were analyzed using repeated measures ANOVA. The analysis revealed a significant main effect of time ($p < 0.001$), a significant main effect of group ($p < 0.001$), and a significant time per group interaction ($p < 0.001$). Simple main effects analyses and subsequent LSD post-hoc tests were performed to compare MAP between groups at each time point. At T0, there was no statistically significant difference in MAP between the group RT and the group P. At T1, both groups showed a decrease in MAP compared to T0. The LSD post-hoc test revealed a statistically significant difference between the two groups, with the group RT exhibiting a significantly higher MAP than the group P (group RT: 82.84 ± 8.09 mmHg *vs* group RT: 77.20 ± 9.87 mmHg; $p < 0.001$). At T2, MAP increased in both groups relative to T1, and the difference between groups remained statistically significant, with the group RT maintaining a higher MAP than the group P (group RT: 88.43 ± 10.13 mmHg *vs* group P: 83.50 ± 8.83 mmHg; $p < 0.001$). At T3, MAP declined in both groups compared to T2, but the group RT maintained a significantly higher MAP than the group P (group RT: 82.76 ± 4.28 mmHg *vs* group P: 78.08 ± 4.81 mmHg; $p < 0.001$). At T4, a slight increase in MAP was observed in both groups relative to T3. However, LSD post-hoc test indicated that the difference in MAP between the group RT and the group P was not statistically significant at this time point (Table 3).

Fig. 1 illustrates the trends of MAP changes in the two groups over time. From T0 to T1, the decrease in MAP appeared more pronounced in the group P than in the group RT. Between T1 and T3, both groups showed similar patterns, with an initial increase followed by a decrease in MAP. From T3 to T4, the increase in MAP seemed greater in the group P compared to the group RT. Overall, Fig. 1 visually supports the observation that MAP fluctuations over time were less pronounced in the group RT.

HR changes over time and between groups were analyzed using repeated measures ANOVA. The analysis revealed a significant main effect of time ($p < 0.001$), a significant main effect of group ($p < 0.001$), and a significant time per group interaction ($p < 0.001$). Simple main effects analyses and subsequent LSD post-hoc tests were performed to compare HR between the two groups at each time point. At T0, there was no statistically significant difference in HR between group RT and group P. At T1, both groups showed a decrease in HR compared to T0. LSD post-hoc test revealed a statistically significant difference between the two groups, with the group RT exhibiting a higher HR than the group P (group RT: 72.30 ± 4.29 bpm *vs* group P: 68.06 ± 4.49 bpm; $p < 0.001$). At T2, HR increased in both groups relative to T1, and the difference between groups remained statistically significant, with the group RT having a higher HR than the group P (group RT: 77.44 ± 5.36 bpm *vs* group P: 73.39 ± 5.20 bpm; $p < 0.001$). At T3, HR decreased in both groups compared to T2, but the group RT continued to exhibit a significantly higher HR than the group P (group RT: 69.47 ± 3.96 bpm *vs* group P: 67.43 ± 4.40 bpm; $p < 0.001$). At T4, a slight increase in HR was observed in

**Table 1. Baseline characteristics of patients.**

| Variables | Group P (n = 115) | Group RT (n = 105) | Statistic | *p* |
|---|---|---|---|---|
| Age (years) | 71.50 ± 4.64 | 70.89 ± 4.17 | t = 1.04 | 0.301 |
| Sex, n (%) | | | $\chi^2$ = 1.61 | 0.205 |
| Female | 80 (69.57) | 81 (77.14) | | |
| Male | 35 (30.43) | 24 (22.86) | | |
| Height (cm) | 164.97 ± 6.37 | 164.66 ± 6.65 | t = 0.35 | 0.726 |
| Weight (kg) | 64.00 (59.00, 75.00) | 62.00 (58.00, 67.00) | Z = –1.94 | 0.053 |
| BMI (kg/m$^2$) | 23.80 (23.18, 25.69) | 23.63 (23.12, 24.62) | Z = –1.68 | 0.093 |
| Hypertension, n (%) | | | $\chi^2$ = 0.09 | 0.762 |
| No | 70 (60.87) | 66 (62.86) | | |
| Yes | 45 (39.13) | 39 (37.14) | | |
| Diabetes, n (%) | | | $\chi^2$ = 0.57 | 0.449 |
| No | 79 (68.70) | 77 (73.33) | | |
| Yes | 36 (31.30) | 28 (26.67) | | |
| CHD, n (%) | | | $\chi^2$ = 0.72 | 0.395 |
| No | 91 (79.13) | 78 (74.29) | | |
| Yes | 24 (20.87) | 27 (25.71) | | |
| ASA, n (%) | | | $\chi^2$ = 0.09 | 0.766 |
| I | 26 (22.61) | 22 (20.95) | | |
| II | 89 (77.39) | 83 (79.05) | | |
| Type of hip fracture, n (%) | | | | |
| Femoral neck fracture | 58 (50.4) | 53 (50.5) | $\chi^2$ = 0.01 | 0.975 |
| Intertrochanteric fracture | 57 (49.6) | 52 (49.5) | | |
| Side of fracture, n (%) | | | | |
| Left | 56 (48.7) | 50 (47.6) | $\chi^2$ = 0.03 | 0.874 |
| Right | 59 (51.3) | 55 (52.4) | | |
| Surgical method, n (%) | | | $\chi^2$ = 0.01 | 0.905 |
| Internal fixation | 44 (38.26) | 41 (39.05) | | |
| Hip replacement | 71 (61.74) | 64 (60.95) | | |
| Duration of surgery (min) | 103.68 ± 9.14 | 103.54 ± 9.55 | t = 0.11 | 0.915 |
| Duration of anesthesia (min) | 122.24 ± 13.30 | 122.00 ± 10.24 | t = 0.15 | 0.880 |

Data are presented as frequency (%), mean ± standard deviation (SD) or median (1st quartile, 3rd quartile). BMI, body mass index; CHD, coronary heart disease; ASA, American Society of Anesthesiologists; RT, remimazolam tosilate; P, propofol.

both groups relative to T3. However, the difference in HR between the group RT and the group P was not statistically significant at this time point (Table 4).

Fig. 2 illustrates the trends of HR changes over time for both groups. From T0 to T1, the decrease in HR appeared more pronounced in the group P than in the group RT. Between T1 and T3, both groups showed similar patterns, with an initial increase followed by a decrease in HR. From T3 to T4, the increase in HR was greater in the group P compared to the group RT. Overall, the data suggest that HR fluctuations over time were less pronounced in the group RT.

To provide a more comprehensive assessment of the hemodynamic management needs of the two groups, we compared the use of vasopressors during surgery (Table 5). The results showed no significant difference between the group RT and the group P in the proportion of patients requiring intervention with norepinephrine, ephedrine, or atropine. Similarly, there was no statistically significant difference between the two groups in the total proportion of patients requiring at least one vasopressor intervention.

No severe adverse events, such as intraoperative awareness, were observed in either group. Among intraoperative adverse events, the occurrence of injection pain was significantly lower in the group RT compared to the group P (group RT: 6 [5.71] *vs* group P: 16 [13.91]; $p = 0.043$). There were no statistically significant differences between the two groups in the incidence of hypotension and hypoxemia. Similarly, for postoperative adverse events, no statistically significant differences were found between the groups in the incidence of dizziness, nausea, or vomiting (Table 6).

## Discussion

This retrospective cohort study demonstrates that RT provides anesthetic efficacy comparable to propofol in elderly patients undergoing hip fracture surgery, with notable

**Table 2. Anesthetic effect outcomes.**

| Variables | Group P (n = 115) | Group RT (n = 105) | Statistic | *p* |
|---|---|---|---|---|
| Time from the start of induction to BIS ≤60 (s) | 42.36 ± 7.87 | 43.40 ± 7.43 | t = –1.01 | 0.314 |
| Time from the start of induction to MOAA/S score ≤3 (s) | 45.72 ± 9.28 | 48.22 ± 12.24 | t = –1.69 | 0.092 |
| Time from discontinuation of the drug to extubation (min) | 12.50 ± 1.76 | 7.04 ± 1.41 | t = 25.55 | <0.001 |
| Time from discontinuation of the drug to discharge from the PACU (min) | 38.57 ± 4.30 | 25.20 ± 3.06 | t = 26.73 | <0.001 |

Data are presented as mean ± standard deviation (SD). BIS, bispectral index; MOAA/S, Modified Observer Assessment of Alertness/Sedation; PACU, post-anesthesia care unit.

**Table 3. The MAP of the two groups at different time points.**

| Groups | MAP (mmHg) | | | | |
|---|---|---|---|---|---|
| | T0 | T1 | T2 | T3 | T4 |
| Group P (n = 115) | 93.81 ± 11.20 | 77.20 ± 9.87 | 83.50 ± 8.83 | 78.08 ± 4.81 | 83.08 ± 8.89 |
| Group RT (n = 105) | 92.71 ± 8.99 | 82.84 ± 8.09 | 88.43 ± 10.13 | 82.76 ± 4.28 | 84.84 ± 8.09 |
| F time, *p* time | 85.933, <0.001 | | | | |
| F group, *p* group | 37.606, <0.001 | | | | |
| F interaction, *p* interaction | 5.886, <0.001 | | | | |
| Post-hoc, *p* | 0.344 | <0.001 | <0.001 | <0.001 | 0.130 |

Data are presented as mean ± standard deviation (SD), with the units in mmHg. T0, before induction; T1, immediately after induction; T2, immediately after tracheal intubation; T3, one hour after the start of surgery; T4, at the end of surgery. MAP, mean arterial pressure.

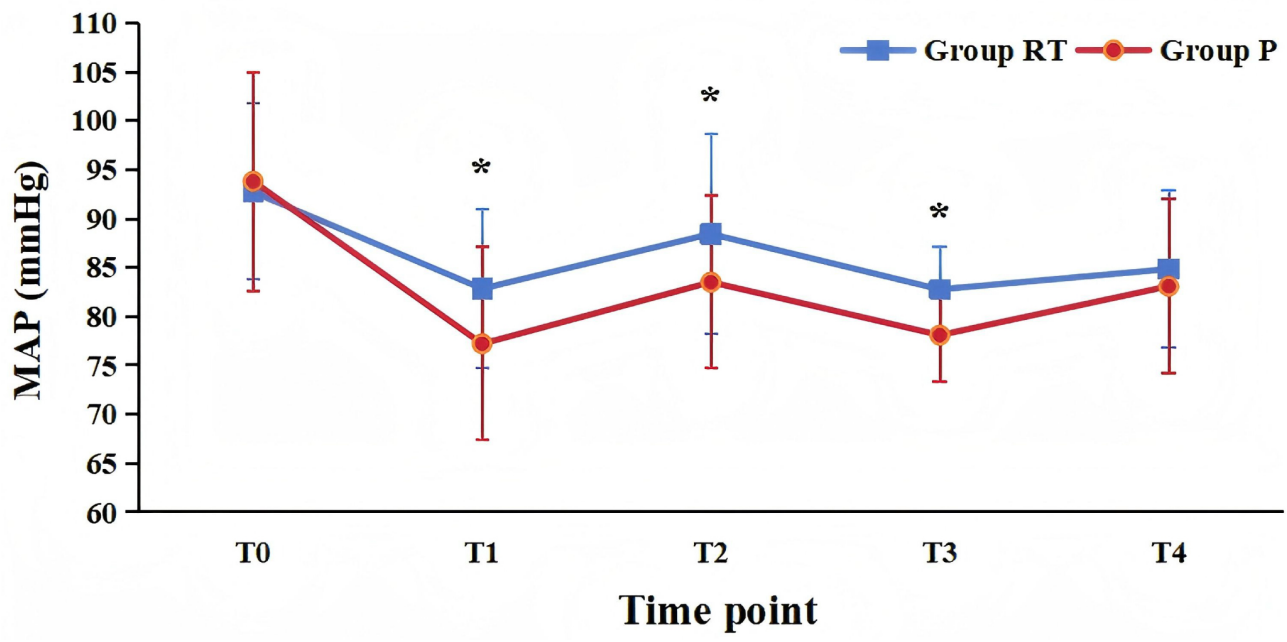


**Fig. 1. The trend of MAP changes in the two groups at different time points.** * Indicates a statistical difference between the two groups. T0, before induction; T1, immediately after induction; T2, immediately after tracheal intubation; T3, one hour after the start of surgery; T4, at the end of surgery. MAP, mean arterial pressure.

advantages in recovery times and hemodynamic stability. RT achieved sedation levels similar to those of propofol, with no significant differences in the time to BIS ≤60 or MOAA/S score ≤3, thereby fulfilling the study's objective of assessing anesthetic effectiveness. However, RT significantly reduced both extubation time and PACU discharge time, consistent with its rapid metabolism by tissue esterases and short offset [4]. The conclusion of "superior hemodynamic stability" in this study is based on intergroup comparisons of MAP and HR data at T1, T2, and T3 time points (as shown in Tables 3,4, and Figs. 1,2). The RT group exhibited smaller decreases in MAP and HR at key anesthetic induction and intraoperative time points compared to the propofol group, with values remaining at relatively higher levels. These findings are consistent with previous reports that RT induces less cardiovascular depression

**Table 4. The HR of the two groups at different time points.**

| Groups | HR (bpm) | | | | |
|---|---|---|---|---|---|
| | T0 | T1 | T2 | T3 | T4 |
| Group P (n = 115) | 75.14 ± 5.73 | 68.06 ± 4.49 | 73.39 ± 5.20 | 67.43 ± 4.40 | 70.17 ± 4.38 |
| Group RT (n = 105) | 75.65 ± 4.83 | 72.30 ± 4.29 | 77.44 ± 5.36 | 69.47 ± 3.96 | 70.70 ± 4.09 |
| F time, *p* time | 102.587, <0.001 | | | | |
| F group, *p* group | 63.678, <0.001 | | | | |
| F interaction, *p* interaction | 8.153, <0.001 | | | | |
| Post-hoc, *p* | 0.424 | <0.001 | <0.001 | 0.001 | 0.404 |

Data are presented as mean ± standard deviation (SD), with the units in bpm. T0, before induction; T1, immediately after induction; T2, immediately after tracheal intubation; T3, one hour after the start of surgery; T4, at the end of surgery.

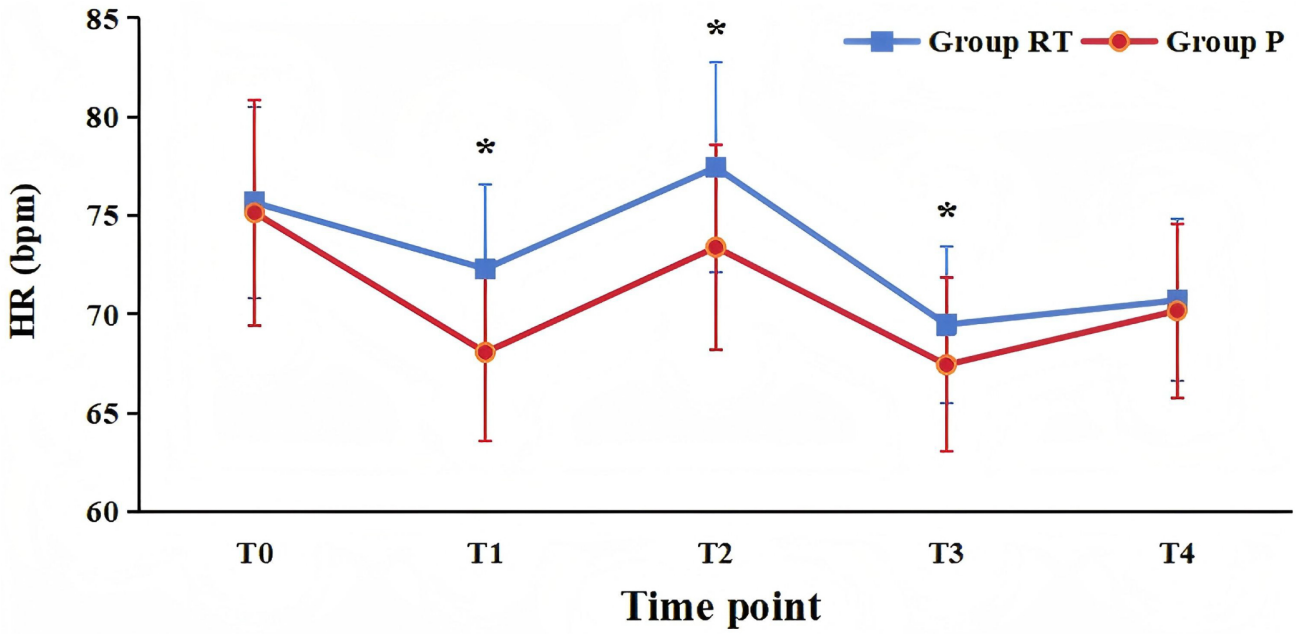


**Fig. 2. The trend of HR changes in the two groups at different time points.** * Indicates a statistical difference between the two groups. T0, before induction; T1, immediately after induction; T2, immediately after tracheal intubation; T3, one hour after the start of surgery; T4, at the end of surgery. HR, heart rate.

than propofol [13]. Additionally, RT was associated with a lower incidence of injection pain—a common issue with propofol—thereby enhancing its safety profile in this vulnerable population [14,15].

Remimazolam's rapid and predictable recovery profile is attributed to its unique pharmacokinetics. It is rapidly hydrolyzed by non-specific tissue esterases, an organ-independent metabolic pathway, leading to minimal accumulation and a consistently short context-sensitive half-time, irrespective of infusion duration [16,17]. This differs markedly from propofol, whose termination of effect relies on redistribution and hepatic metabolism, potentially resulting in slower and less predictable recovery, particularly after prolonged administration [3,17]. Theoretically, remimazolam offers a safety advantage in elderly patients at increased risk of impaired liver and kidney function. This aligns with prior studies showing shorter extubation times with remimazolam compared to propofol in various surgical contexts [18,19]. Although the absolute time differences may have limited impact for individual patients, the consistent and statistically significant trend toward accelerated recovery with RT could improve operating room and PACU turnover efficiency and optimize resource utilization, such as reducing PACU nursing time and bed occupancy. This may be particularly valuable in high-volume surgical centers. However, translating these time savings into cost-effectiveness or significant reductions in workload requires further health economic evaluation. The observed hemodynamic stability with RT is particularly beneficial for elderly patients with hip fractures, who often present with comorbidities that increase the risk of hypotension. Propofol is known to induce hypotension through significant vasodilation and direct myocardial depression [3,20], whereas remimazolam, although acting via GABAergic pathways, generally demonstrates less pronounced negative cardiovascular effects, potentially preserving vascular tone and cardiac

**Table 5. The use of vasopressors during surgery.**

| Variables | Group P (n = 115) | Group RT (n = 105) | Statistic | *p* |
|---|---|---|---|---|
| Phenylephrine, n (%) | | | $\chi^2 = 0.09$ | 0.762 |
| No | 80 (69.57) | 75 (71.43) | | |
| Yes | 35 (30.43) | 30 (28.57) | | |
| Ephedrine, n (%) | | | $\chi^2 = 0.08$ | 0.777 |
| No | 97 (84.35) | 90 (85.71) | | |
| Yes | 18 (15.65) | 15 (14.29) | | |
| Atropine, n (%) | | | $\chi^2 = 0.48$ | 0.490 |
| No | 107 (93.04) | 100 (95.24) | | |
| Yes | 8 (6.96) | 5 (4.76) | | |
| Any vasoactive drug, n (%) | | | $\chi^2 = 0.10$ | 0.751 |
| No | 71 (61.74) | 67 (63.81) | | |
| Yes | 44 (38.26) | 38 (36.19) | | |

Data are presented as frequency (%).

**Table 6. Incidence of anesthesia-related adverse events.**

| Variables | Group P (n = 115) | Group RT (n = 105) | Statistic | *p* |
|---|---|---|---|---|
| Hypotension, n (%) | | | $\chi^2 = 2.68$ | 0.102 |
| No | 94 (81.74) | 94 (89.52) | | |
| Yes | 21 (18.26) | 11 (10.48) | | |
| Hypoxemia, n (%) | | | $\chi^2 = 0.53$ | 0.468 |
| No | 103 (89.57) | 97 (92.38) | | |
| Yes | 12 (10.43) | 8 (7.62) | | |
| Dizziness, n (%) | | | $\chi^2 = 2.48$ | 0.115 |
| No | 107 (93.04) | 91 (86.67) | | |
| Yes | 8 (6.96) | 14 (13.33) | | |
| Nausea and vomiting, n (%) | | | $\chi^2 = 3.73$ | 0.053 |
| No | 95 (82.61) | 96 (91.43) | | |
| Yes | 20 (17.39) | 9 (8.57) | | |
| Injection pain, n (%) | | | $\chi^2 = 4.10$ | 0.043 |
| No | 99 (86.09) | 99 (94.29) | | |
| Yes | 16 (13.91) | 6 (5.71) | | |

Data are presented as frequency (%).

function more effectively [14,21]. While BIS values were slightly higher with RT, as noted in laparoscopic cholecystectomy studies [22], no cases of intraoperative awareness were reported, suggesting adequate anesthetic depth. The lower incidence of injection pain further supports RT's tolerability, consistent with findings in gastrointestinal endoscopy [23]. Nevertheless, these results should be interpreted cautiously due to the retrospective design and the potential for unmeasured confounders. Despite these limitations, our findings align with the broader evidence supporting the efficacy and safety of remimazolam [13,14].

The findings of this study are reasonably applicable to elderly patients undergoing orthopedic surgeries, given the pharmacological advantages of RT, such as flumazenil reversibility [24]. However, the patient cohort in this study (mean age 71 years, predominantly ASA I–II) represents a relatively healthy subset of elderly individuals undergoing hip fracture surgery. Therefore, caution is warranted when extrapolating these results to higher-risk populations, such as ASA III–IV patients or those with severe cognitive impairment or multi-organ dysfunction. Although the study was carried out at a single center, the results reflect clinical scenarios in which rapid recovery and stable hemodynamics are priorities, supporting the utility of RT in similar settings with tailored anesthesia protocols. Limitations include the retrospective design, which may introduce selection bias; however, baseline matching was conducted to mitigate some confounding factors. The lack of long-term follow-up, such as postoperative cognitive outcomes, restricts a full safety evaluation. For secondary outcomes with lower event rates (such as specific types of hypotension or hypoxemia), the current sample size may lack sufficient statistical power to detect clinically meaningful differences. Future studies should conduct power calculations based on anticipated effect sizes to ensure adequate sample size. As a retrospective study, we did not systematically collect or analyze data on postoperative delirium (POD) or 30-day mortality. Additionally, detailed respiratory param-

eters, such as minute ventilation or end-tidal $CO_2$, were not systematically recorded or analyzed, which may have impacted the detection of subtle respiratory depression. This study primarily assessed objective time points for anesthesia recovery and the incidence of adverse events, but did not systematically collect standardized recovery quality scores, such as 15-item quality of recovery (QoR-15). This is an important limitation, and future research should include tools like the QoR-15 to comprehensively evaluate postoperative recovery quality. Furthermore, this study did not include a specific subgroup analysis for patients over 75 years old; consequently, the impact of age on the relative effectiveness of the two drugs was not fully explored, which constitutes an additional limitation. However, these constraints do not undermine the primary findings of this study, and larger prospective studies are required to address these gaps.

## Conclusions

In conclusion, RT provides effective anesthesia for ASA I–II elderly patients undergoing hip fracture surgery, offering faster recovery and greater hemodynamic stability compared to propofol. Its favorable safety profile, including reduced injection pain, positions RT as a valuable alternative in this population. Further research is warranted to validate its long-term outcomes.

## Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Author Contributions

JL designed and performed the research and wrote the paper; QW designed the research and supervised the report; JW designed the research and contributed to the analysis. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

## Ethics Approval and Consent to Participate

The research received approval from the Ethics Committee of Luxian People's Hospital (Approval No. 20240016). This study adhered to the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants.

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## Conflict of Interest

The authors declare no conflict of interest.

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