BMC Anesthesiology

RESEARCH

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Comparison of remimazolam tosylate and propofol in hemodynamic stability, postoperative cognitive function, and recovery in general anesthesia combined with regional nerve blocks: a retrospective cohort study

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Abstract

Background General anesthesia (GA) combined with regional anesthesia (RA) is commonly used to enhance perioperative analgesia and hemodynamic stability. This study aimed to compare the hemodynamic effects and postoperative cognitive function between remimazolam tosylate and propofol in patients undergoing GA combined with RA.

Methods A retrospective cohort study was conducted on 4408 patients who underwent elective upper or lower limb surgeries at our institution from January 2020 to June 2024. Patients were divided into two groups: Remimazolam ($n=2391$) and Propofol ($n=2017$). The primary outcomes included hemodynamic parameters (systolic blood pressure [SBP], diastolic blood pressure [DBP], heart rate [HR], mean arterial pressure [MAP]) and postoperative cognitive function (Montreal Cognitive Assessment [MoCA] scores at 24, 48, and 72 h). Secondary outcomes included anesthetic drug consumption, adverse events, and recovery times.

Results The Remimazolam group was associated with more stable hemodynamic parameters, with significantly higher SBP (121.4 ± 8.3 vs. 112.6 ± 9.2 mmHg, $p<0.05$), DBP (72.3 ± 6.1 vs. 67.8 ± 5.9 mmHg, $p<0.05$), and MAP (88.3 ± 7.4 vs. 83.1 ± 7.2 mmHg, $p<0.05$) compared to the Propofol group. Postoperative cognitive function was superior in the Remimazolam group, with higher MoCA scores at 24, 48, and 72 h (19.6 ± 2.1 vs. 16.3 ± 3.4 at 24 h, $p<0.05$). The Remimazolam group also had lower anesthetic consumption (0.16 ± 0.02 vs. 2.4 ± 0.3 mg/kg, $p<0.05$), faster recovery times (extubation 8.4 ± 2.1 vs. 11.2 ± 3.4 min, $p<0.05$), and fewer adverse events (hypotension: 14% vs. 28%, $p<0.05$).

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Conclusion *Remimazolam tosylate was associated with more stable hemodynamic parameters, lower rates of postoperative cognitive dysfunction, and shorter recovery times compared to propofol* in patients undergoing GA combined with RA, suggesting it may be a safer alternative for patients.

Keywords Remimazolam, Propofol, General anesthesia, Regional anesthesia, Hemodynamics, Postoperative cognitive function, Recovery time

Introduction

Anesthesia plays a pivotal role in ensuring the successful completion of surgical procedures by providing analgesia, unconsciousness, and maintaining hemodynamic stability throughout the perioperative period. General anesthesia (GA) serves as the foundation of modern surgical practice, inducing a reversible loss of consciousness and autonomic function, thereby allowing for pain-free surgeries. However, while achieving adequate anesthesia, anesthesiologists must also address perioperative complications, minimize adverse effects, and promote efficient postoperative recovery. To achieve these goals, the combination of regional anesthesia (RA) with GA has become a widely adopted strategy. This combined approach enhances analgesia, reduces the stress response, and helps maintain hemodynamic stability, ultimately improving recovery outcomes and reducing complications related to surgical stress [1, 2].

Despite these advantages, the combination of GA and regional nerve blocks presents challenges, particularly in managing hemodynamic changes such as hypotension, which may be exacerbated by the vasodilatory effects of regional anesthesia [3]. Consequently, the selection of anesthetic agents is critical, not only for inducing anesthesia but also for maintaining stable hemodynamics and facilitating rapid recovery. Traditional agents like midazolam and propofol are commonly used due to their rapid onset and recovery profiles; however, they are associated with limitations, including cardiovascular instability, respiratory depression, and delayed emergence from anesthesia, complicating perioperative management [4, 5].

Remimazolam tosylate, a novel ultra-short-acting benzodiazepine, has emerged as a promising alternative to traditional sedatives such as propofol. By acting on GABA_A receptors, remimazolam induces sedation with several distinct advantages over conventional agents. These include rapid onset, rapid metabolism, and minimal impact on hemodynamics, making it particularly suitable for patients undergoing complex surgeries with combined GA and regional anesthesia. Moreover, remimazolam has a favorable safety profile, with fewer instances of injection pain, respiratory depression, and cardiovascular side effects compared to propofol [6–9]. These properties have led to increasing interest in its use across a range of surgical populations, including both low- and high-risk patients, with studies supporting its efficacy and safety in various clinical settings [6, 10–11].

This study aims to compare the hemodynamic effects and postoperative cognitive outcomes of remimazolam tosylate and propofol in patients undergoing GA combined with regional nerve blocks. Specifically, we focus on hemodynamic stability, the incidence of hemodynamic instability, and cognitive recovery post-surgery. Our hypothesis is that remimazolam will provide superior hemodynamic stability and enhanced cognitive recovery compared to propofol [12].

The significance of this study lies in its potential to redefine anesthetic management for complex surgeries, especially in high-risk populations such as the elderly or patients with cardiovascular comorbidities. Given the increasing interest in remimazolam as a safer alternative to traditional anesthetics, the findings of this study could lead to more tailored, individualized anesthesia protocols. This would not only improve short-term recovery but also enhance long-term outcomes for patients undergoing combined GA and regional anesthesia. Ultimately, the results could have significant clinical implications, enhancing patient safety, optimizing recovery, and reducing perioperative complications across a variety of settings.

Methods

Study design and setting

This retrospective, single-center cohort study utilized data from the Sichuan Provincial Disease Control Center (website: https://www.sccdc.cn/), which compiles records from multiple hospitals within Sichuan Province.

This study was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013). Ethical approval for the study was obtained from the Institutional Review Board (IRB) of the Sichuan Provincial Disease Control Center (IRB approval number: 2015-SCDCC-078) and the Ziyang Central Hospital IRB (approval number: 2019 – 185). Written informed consent was acquired from all participants prior to enrollment.

Inclusion and exclusion criteria

All preoperative evaluations in this study were conducted in accordance with the updated guidelines of the European Society of Anaesthesiology and Intensive Care (ESAIC) [13].

Inclusion criteria for the study were as follows: (1) aged between 18 and 64 years, (2) scheduled for elective upper or lower limb surgery, (3) classified as American Society of Anesthesiologists (ASA) physical status I or II, and (4) a Body Mass Index (BMI) between 18 and 30 kg/m². Exclusion criteria included: (1) pregnancy or lactation, (2) known allergies to local anesthetics or study medications, (3) significant history of cardiovascular or cerebrovascular diseases, (4) uncontrolled hypertension or hypotension (systolic BP > 160 mmHg or < 90 mmHg), (5) severe arrhythmias or unstable angina, (6) neurological or psychiatric disorders, (7) communication difficulties, (8) substance abuse within the past two years, and (9) participation in other clinical trials within the three months preceding the study.

Data management

Standardization of data collection

All participating hospitals adopted a unified electronic medical record template, which included preset fields (such as hemodynamic parameters and MoCA scores).

The data extraction was carried out by two independent researchers, and inconsistent entries were resolved through cross-checking (concordance test $\kappa = 0.89$).

Logical verification and cleaning

Records with blood pressure values beyond the physiological range (SBP < 50 or > 250 mmHg) and those with more than 20% of MoCA scores missing ($n = 62$) were excluded.

Sensitivity analysis was conducted for extreme values (such as removing individuals with MAP fluctuations > 3 SD), and the results showed that the conclusions did not change substantially.

Device calibration and operational specifications

All blood pressure monitoring devices were calibrated quarterly according to hospital standards.

Operators of regional nerve blocks were required to have at least 5 years of experience in ultrasound guidance and pass the in-hospital qualification certification.

Sample size calculation

Sample size calculations were based on primary outcomes, specifically the mean arterial pressure (MAP) and Montreal Cognitive Assessment (MoCA) scores at entry to the Post Anesthesia Care Unit (PACU) (T3). Assuming a significance level (α) of 0.05, a power ($1 - \beta$) of 0.8, and a 1:1 allocation ratio, the required minimum sample size was calculated to be 4408 participants (2204 per group), with an adjustment for potential dropouts.

Anesthesia protocol

Preoperative Preparation

All patients underwent a 6-hour fasting period and a 2-hour water restriction prior to surgery. Peripheral intravenous access was established, and intravenous fluids were administered following the 4:2:1 rule. Routine monitoring included electrocardiogram (ECG), non-invasive blood pressure (NIBP), pulse oximetry, and Bispectral Index (BIS) monitoring to assess the depth of anesthesia.

Regional nerve Blockade

Ultrasound-guided regional nerve blockade was performed according to the surgical site. Success of the blockade was confirmed 30 min post-injection using a needle prick test. Patients in whom the blockade was unsuccessful were excluded and managed with general anesthesia only.

General anesthesia

In both sets of experiments, we used the same dose of 0.40.6 μ g / kg Sufentanil.

Remimazolam group Induction: 0.4–0.6 μg/kg Sufentanil, 0.3 mg/kg Remimazolam Tosylate, and 1.5 mg/kg cis-atracurium. Maintenance: Continuous infusion of Remimazolam Tosylate at an initial rate of 1 mg/kg/h, titrated to maintain a BIS range of 40–60. The infusion rate was increased by 0.2 mg/kg/h every 2 min, up to a maximum rate of 1.5 mg/kg/h. Additional Sufentanil and cis-atracurium were administered as necessary. Termination: Infusion was discontinued upon skin closure, and reversal agents (Neostigmine 1 mg and Atropine 0.5 mg) were administered once spontaneous breathing resumed.

Propofol group Induction: 0.4–0.6 μg/kg Sufentanil, 2 mg/kg Propofol, and 1.5 mg/kg cis-atracurium. Maintenance: Continuous infusion of Propofol at an initial rate of 6 mg/kg/h, titrated to maintain a BIS range of 40–60. The infusion rate was increased by 1 mg/kg/h every 2 min, up to a maximum rate of 10 mg/kg/h. Additional Sufentanil and cis-atracurium were administered as required. Termination: Infusion was discontinued upon skin closure, with reversal agents administered as necessary.

Primary and secondary outcomes

Primary outcomes

The primary outcomes included changes in hemodynamic parameters (systolic blood pressure, diastolic blood pressure, heart rate, and mean arterial pressure) at four key time points: preoperatively (T0), immediately after induction (T1), 10 min after surgery onset (T2), and 30 min after surgery onset (T3). Postoperative cognitive function was assessed using the Montreal Cognitive

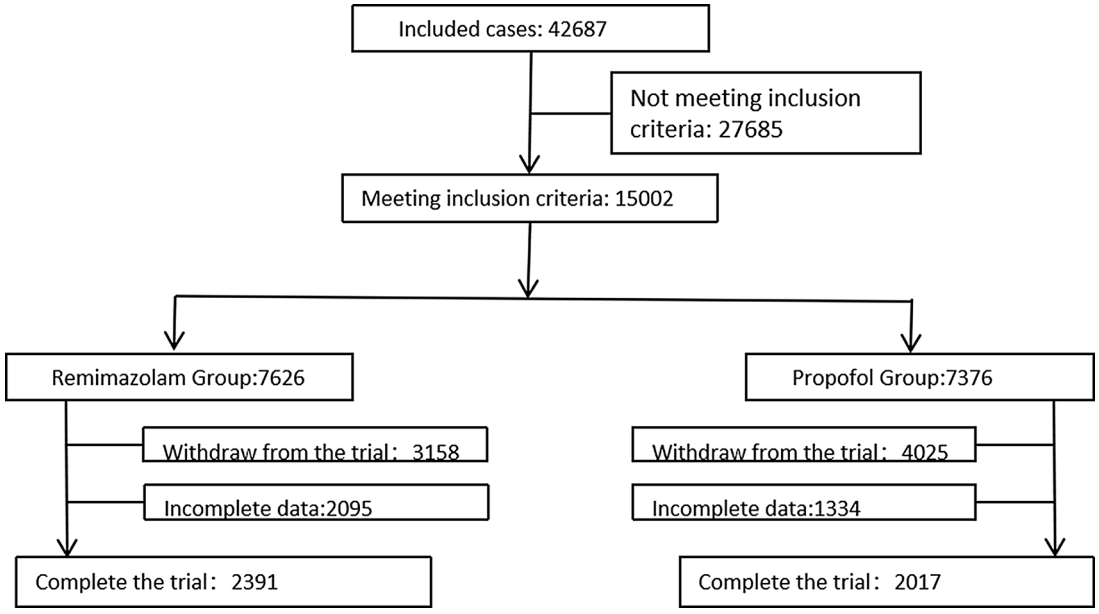

Fig. 1 Trial process

Assessment (MoCA) at 24 h (POCD-24 h), 48 h (POCD-48 h), and 72 h (POCD-72 h) postoperatively.

Secondary outcomes

Secondary outcomes included intraoperative anesthetic drug consumption, anesthesia quality (measured using the Ramsay Sedation Scale, RSS), incidence of adverse events (hypotension, bradycardia, and respiratory depression), and postoperative recovery times, including time to extubation and time to PACU discharge.

Statistical analysis

Statistical analysis was conducted using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means ± standard deviations and compared between groups using independent t-tests. Categorical variables were presented as frequencies and percentages, and differences between groups were assessed using chi-square tests. A p-value of <0.05 was considered statistically significant.

Results

Study overview

This retrospective, single-center cohort study aimed to evaluate the effects of Remimazolam Tosylate (Remimazolam) and Propofol on hemodynamic stability, intraoperative anesthetic drug consumption, and postoperative cognitive recovery in patients undergoing general anesthesia combined with regional nerve blockade. A total of 4408 patients were included, with 2391 assigned to the Remimazolam group and 2017 to the Propofol group. The trial flow is depicted in Fig. 1. The primary and secondary outcomes, including hemodynamic changes, drug consumption, postoperative cognitive function, adverse events, and recovery times, are summarized below.

Table 1 Demographic and clinical characteristics of patients

Characteristic	Remimazolam Group ($n=2391$)	Propofol Group ($n=2017$)	*p*-value
Age (years)	46.2 ± 8.5	45.8 ± 8.2	0.83
Sex (Male/Female)	1195/1196	1008/1009	0.85
BMI (kg/m^2)	24.1 ± 2.8	23.9 ± 2.6	0.78
ASA Physical Status I-II	100%	100%	--

Demographic and clinical characteristics

The baseline demographic and clinical characteristics of participants were comparable between the two groups. The Remimazolam group ($n=2391$) and Propofol group ($n=2017$) exhibited no significant differences in age, sex, body mass index (BMI), or American Society of Anesthesiologists (ASA) physical status classification ($p>0.05$). Detailed demographic data are presented in Table 1.

Intraoperative hemodynamics

Hemodynamic stability was assessed at four key time points: preoperatively (T0), immediately after induction (T1), 10 min after surgery onset (T2), and 30 min after surgery onset (T3). At all time points, the Remimazolam group demonstrated greater hemodynamic stability than the Propofol group. Specifically, systolic blood pressure (SBP) in the Remimazolam group decreased by 7.3% ± 3.4% at T1, 9.2% ± 3.1% at T2, and 10.1% ± 3.5% at T3. In contrast, the Propofol group showed greater reductions: 12.5% ± 4.2%, 14.3% ± 5.1%, and 15.8% ± 5.3% at T1, T2, and T3, respectively ($p<0.05$). Similarly,

diastolic blood pressure (DBP) in the Remimazolam group remained more stable, with a decrease of 12.4% ± 4.2% at T3 compared to 18.1% ± 5.5% in the Propofol group ($p < 0.05$). Heart rate (HR) was also more stable in the Remimazolam group at T1, with an increase of 4.8% ± 2.1% compared to 7.6% ± 3.2% in the Propofol group ($p < 0.05$). In terms of mean arterial pressure (MAP), the Remimazolam group exhibited smaller reductions: 5.2% ± 2.3%, 6.4% ± 2.8%, and 7.5% ± 3.1% at T1, T2, and T3, respectively, compared to 10.1% ± 3.9%, 12.2% ± 4.1%, and 13.5% ± 4.3% in the Propofol group ($p < 0.05$). These hemodynamic changes are illustrated in Fig. 2.

Intraoperative anesthetic drug consumption

Intraoperative drug consumption was significantly lower in the Remimazolam group compared to the Propofol group. For induction, the Remimazolam group required 0.18 ± 0.04 mg/kg, whereas the Propofol group required 2.5 ± 0.5 mg/kg ($p < 0.05$). For maintenance, the Remimazolam group received 0.08 ± 0.02 mg/kg/h, compared to 4.1 ± 0.6 mg/kg/h in the Propofol group ($p < 0.05$). These differences in drug consumption were statistically significant and are highlighted in Fig. 3.

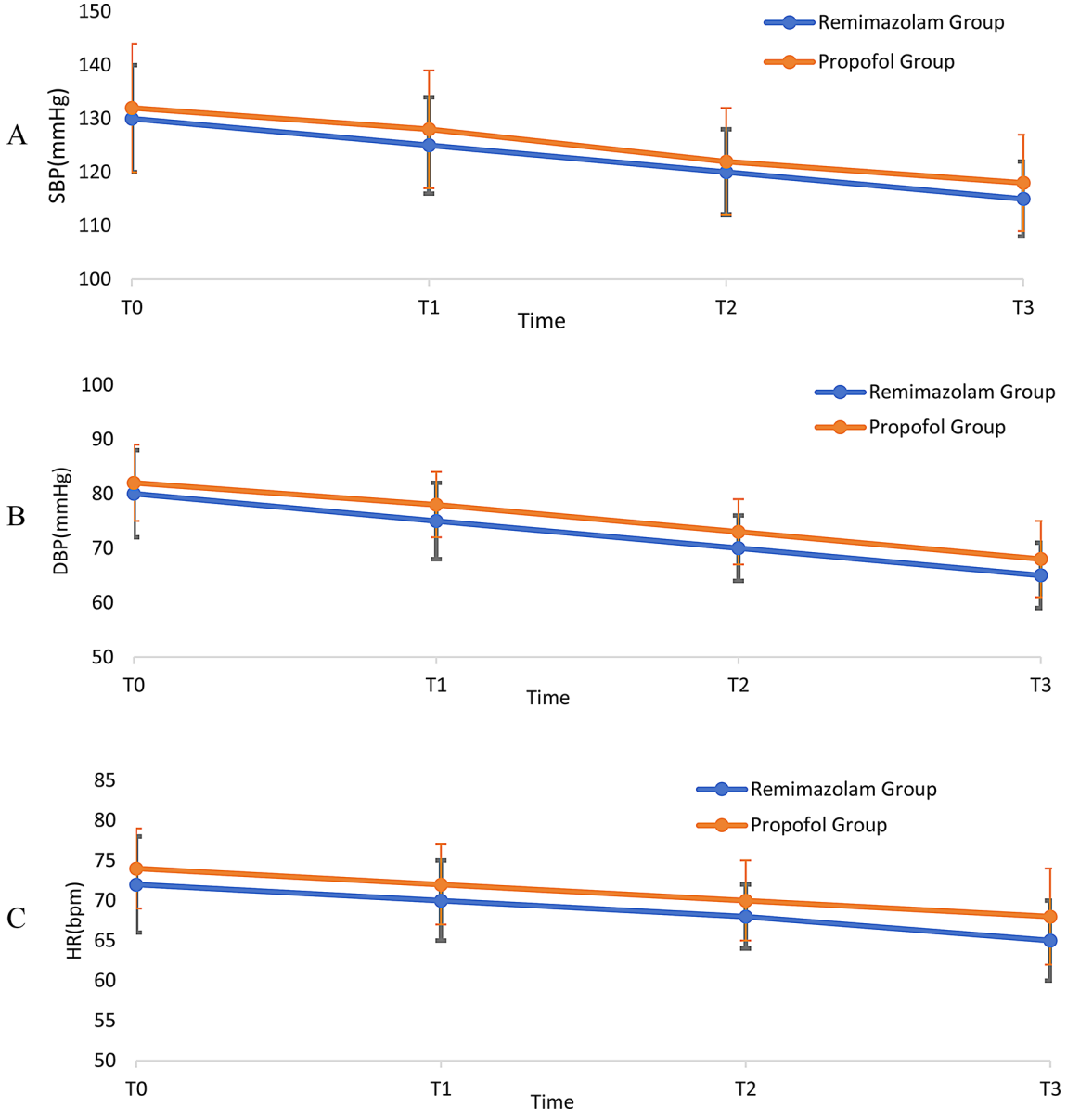

Fig. 2 Hemodynamic Changes during Anesthesia: (**A**: Systolic Blood Pressure at T0, T1, T2, and T3 in the remimazolam and propofol groups; **B**: Diastolic Blood Pressure at T0, T1, T2, and T3 in the remimazolam and propofol groups; **C**: Heart Rate at T0, T1, T2, and T3 in the remimazolam and propofol groups)

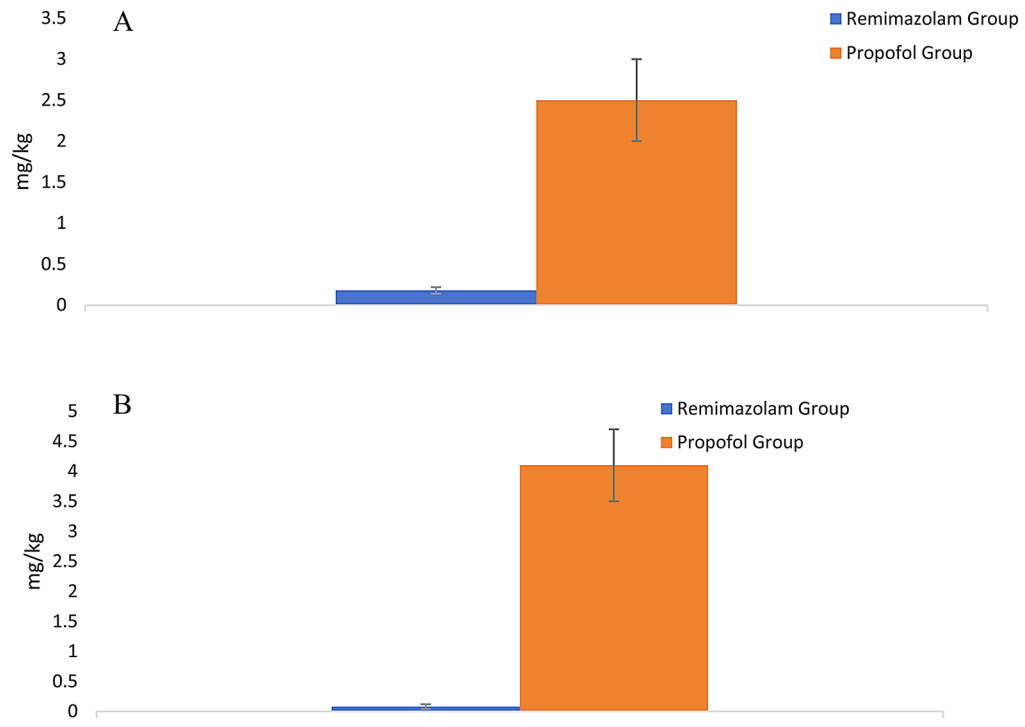

Fig. 3 Total drug consumption during anesthesia induction and maintenance (**A**: Total dose of remimazolam vs. propofol for induction; **B**: Total dose of remimazolam vs. propofol for maintenance.)

Postoperative cognitive function (POCD)

Postoperative cognitive function was evaluated at 24 h (POCD-24 h), 48 h (POCD-48 h), and 72 h (POCD-72 h) postoperatively. The Remimazolam group demonstrated significantly better cognitive function at each time point. At POCD-24 h, the mean cognitive function score in the Remimazolam group was 19.6 ± 2.1, significantly higher than the Propofol group, which had a score of 16.3 ± 3.4 ($p < 0.05$). This difference was consistent at POCD-48 h and POCD-72 h, with the Remimazolam group consistently outperforming the Propofol group ($p < 0.05$). The incidence of cognitive dysfunction was also lower in the Remimazolam group, with 12% of patients exhibiting cognitive dysfunction at POCD-24 h, compared to 26% in the Propofol group ($p < 0.05$). These trends continued at POCD-48 h and POCD-72 h ($p < 0.05$). These findings are presented in Fig. 4.

Incidence of adverse events

The incidence of adverse events, including hypotension, bradycardia, and respiratory depression, was monitored throughout the perioperative period. The Remimazolam group had a significantly lower incidence of hypotension, occurring in 14% of patients, compared to 28% in the Propofol group ($p < 0.05$). No significant difference was observed in the incidence of bradycardia (8% in the Remimazolam group vs. 10% in the Propofol group, $p > 0.05$) or respiratory depression (5% in the Remimazolam group vs. 6% in the Propofol group, $p > 0.05$). The incidence of adverse events is summarized in Table 2.

Postoperative recovery time

Recovery times were significantly shorter in the Remimazolam group. The time to extubation was 8.4 ± 2.1 min in the Remimazolam group, compared to 11.2 ± 3.4 min in the Propofol group ($p < 0.05$). Additionally, the time to discharge from the Post Anesthesia Care Unit (PACU) was 90.3 ± 12.5 min for the Remimazolam group, compared to 112.6 ± 16.2 min for the Propofol group ($p < 0.05$).

Discussion

This study aimed to compare the effects of Remimazolam Tosylate (Remimazolam) and Propofol on hemodynamics, drug consumption, postoperative cognitive dysfunction (POCD), and complication rates in patients undergoing general anesthesia combined with regional nerve blockade. Our results demonstrate that while Remimazolam offers some advantages, including higher postoperative cognitive scores, shorter recovery times compared and more stable hemodynamics, it requires higher drug consumption compared to Propofol. These findings are discussed below, incorporating existing literature, clinical implications, and the study's limitations.

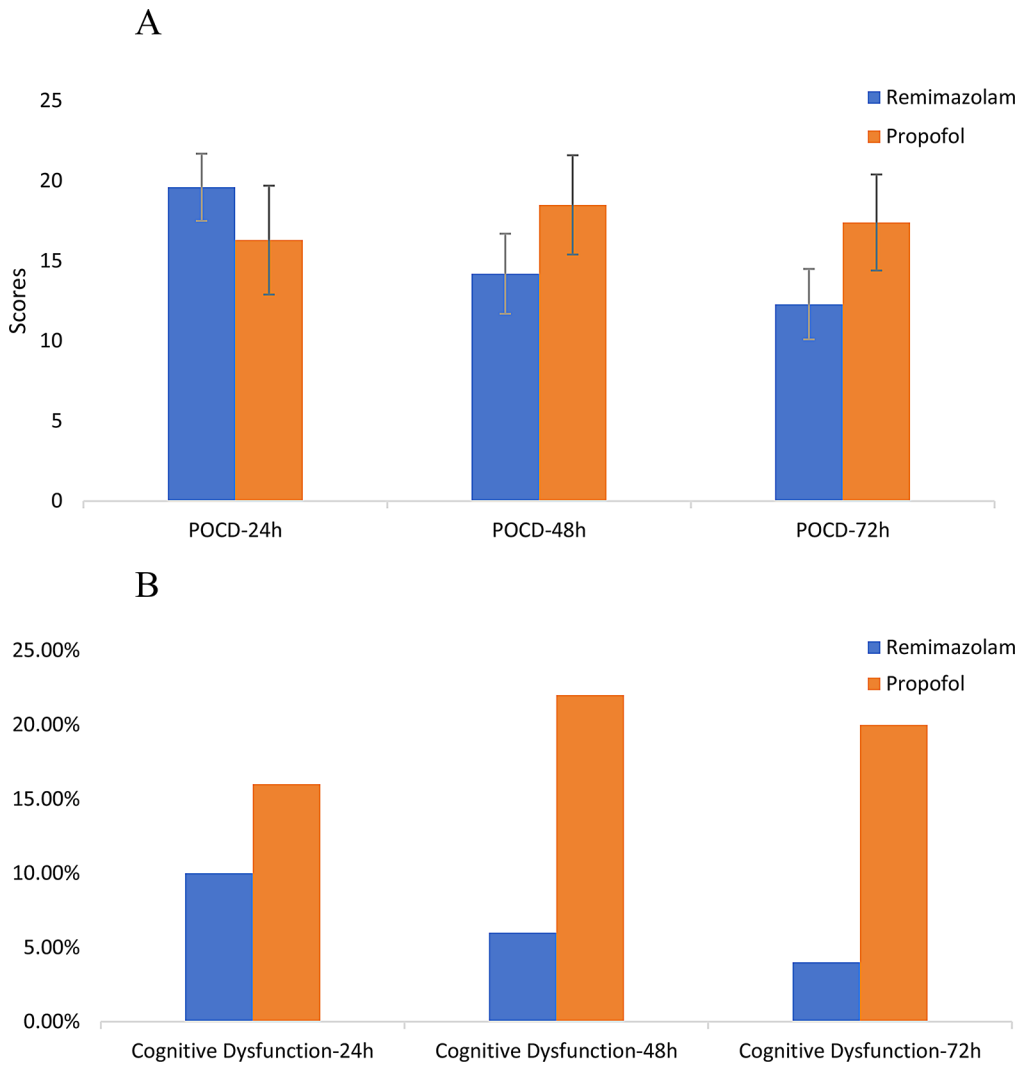

Fig. 4 Postoperative Cognitive Function Recovery (POCD) (**A**: POCD scores at 24, 48, and 72 h in the remimazolam and propofol groups; **B**: Incidence of cognitive dysfunction at 24, 48, and 72 h in the remimazolam and propofol groups.Statistical significance: $p < 0.05$ for all comparisons between groups)

Table 2 Incidence of adverse events

Adverse Event	Remimazolam Group ($n = 2391$)	Propofol Group ($n = 2017$)	*p*-value
Hypotension (%)	14	28	< 0.05
Bradycardia (%)	8	10	> 0.05
Respiratory Depression (%)	5	6	> 0.05

Hemodynamic stability

Hemodynamic stability is critical for patient safety during anesthesia, particularly in those with underlying cardiovascular conditions. In this study, both Remimazolam and Propofol groups showed stable hemodynamic profiles, with no significant differences in blood pressure or heart rate at key time points. This is consistent with previous studies suggesting that Remimazolam does not induce significant cardiovascular depression, even in high-risk patients [14–16]. For example, Doi et al. found that Remimazolam maintained stable hemodynamics during major surgeries, especially in patients with comorbidities [10].

In contrast, Propofol is known to have dose-dependent cardiovascular effects, such as hypotension and bradycardia, which can complicate anesthesia management, particularly in elderly patients or those with pre-existing cardiovascular conditions [17–19]. Our findings support the hypothesis that the use of Remimazolam was correlated with fewer adverse events, suggesting it could be considered as a potential alternative to Propofol in specific clinical scenarios, particularly in high-risk populations. While both drugs maintained stable hemodynamic conditions, the faster metabolism of Remimazolam likely contributed to its faster recovery times. Remimazolam is rapidly metabolized by esterases in the liver, leading to quicker clearance from the body [19, 20], which is advantageous in elderly or high-risk patients who may be more

sensitive to the prolonged effects of Propofol, especially when hypotension occurs during surgery [21].

Drug consumption

In the Remimazolam Group and the Propofol Group, the same 0.4–0.6 μg /kg Sufentanil and 1.5 mg/kg cisatracurium were used during the induction of General Anesthesia. We found that the significantly lower drug consumption in the Remimazolam group compared to the Propofol group. This contrasts with some previous studies suggesting that Remimazolam requires more frequent dosing or higher doses to maintain adequate anesthesia throughout the procedure [7]. However, in this study, patients receiving Remimazolam required significantly less anesthetic for both induction and maintenance [11]. The lower consumption of Remimazolam may be attributed to its pharmacokinetic properties, including its rapid onset, efficient metabolism by tissue esterases, and ability to maintain stable anesthesia with minimal dose adjustments. In contrast, Propofol, despite its continuous infusion administration, required higher total dosages to achieve and sustain anesthesia, likely due to its greater propensity for cardiovascular depression and dose-dependent hemodynamic instability [22].

Despite the lower drug consumption, the benefits of Remimazolam—such as enhanced hemodynamic stability, faster recovery times, and a reduced incidence of cardiovascular complications (e.g., hypotension and bradycardia)—remain significant. Some studies suggest that while Propofol remains a widely used agent, Remimazolam's favorable recovery profile and lower incidence of side effects may improve clinical outcomes, particularly in high-risk patients and outpatient procedures. Further research is warranted to assess the cost-effectiveness of Remimazolam compared to Propofol, especially in short-duration surgeries and ambulatory care settings, where rapid recovery and minimal postoperative complications are critical [23].

Postoperative cognitive dysfunction (POCD)

A notable finding in this study was the superior cognitive recovery observed in the Remimazolam group, as evidenced by significantly lower POCD scores at 24, 48, and 72 h postoperatively compared to the Propofol group. POCD is a well-established complication of anesthesia, particularly in elderly patients, and it can significantly affect long-term recovery and quality of life [24–26]. Although the exact mechanism behind POCD remains unclear, it is hypothesized that the cumulative effects of anesthetics on the central nervous system, particularly in older individuals, may contribute to cognitive dysfunction [24–26].

The faster clearance of Remimazolam may have minimized its impact on cognitive function, facilitating quicker cognitive recovery. This finding is consistent with the work of Moller et al. (1998), which indicated that Propofol was associated with prolonged cognitive dysfunction in elderly patients, whereas newer anesthetics like Remimazolam demonstrated improved cognitive outcomes [24]. Given the increasing concerns regarding cognitive decline in elderly surgical patients, the cognitive benefits of Remimazolam are particularly relevant. Its rapid metabolism and lower cumulative dose at the time of extubation may significantly reduce the incidence of POCD, offering a critical advantage in high-risk populations prone to postoperative cognitive decline.

Complication rates

In terms of complications, we found no significant differences between the Remimazolam and Propofol groups regarding bradycardia or respiratory depression. These findings align with prior studies, such as Doi et al., which reported similar safety profiles for both agents during major surgeries [10]. Propofol is known to induce hypotension and bradycardia, particularly in high-risk patients, while Remimazolam's unique pharmacokinetic profile, characterized by rapid clearance, may reduce the incidence of cardiovascular complications [27–29].

Moreover, the more predictable pharmacological profile of Remimazolam could explain its lower incidence of respiratory depression compared to Propofol, which is associated with a higher risk of respiratory complications, especially at higher doses [30, 31]. While Remimazolam's overall safety profile appears favorable, further studies are needed to explore specific complications associated with its use in diverse patient populations, such as those with liver dysfunction or genetic variations that affect esterase activity [10].

Extubation and recovery time

The Remimazolam group exhibited significantly shorter extubation times and faster discharge from the PACU compared to the Propofol group. These findings are consistent with previous studies, which have demonstrated that Remimazolam enables faster recovery from anesthesia [32, 33]. The rapid recovery observed in our study is especially relevant for outpatient procedures, where early discharge is essential for patient satisfaction and cost-effectiveness. Additionally, the faster return to consciousness provided by Remimazolam is beneficial for elderly patients, who may be more sensitive to the sedative effects of Propofol.

Limitations of the study

First, the study population is restricted to patients aged 18–64 years undergoing upper and lower limb surgeries, excluding those with severe cardiac conditions or other high-risk factors. This restriction may reduce the

generalizability of the findings to other surgical procedures or patient demographics. Expanding the study population to include a wider age range and diverse surgical types in future multicenter trials would improve external validity.

Second, as a retrospective cohort study, this research is inherently more susceptible to selection bias and confounding factors compared to prospective studies. The data were collected from multiple hospitals within Sichuan Province between January 2020 and June 2024 using a non-random sampling method, which may introduce bias and limit the generalizability of the findings. To strengthen the evidence base, future studies should consider conducting prospective, randomized, controlled trials (RCTs).

Third, the lack of subgroup analyses is another limitation. The study did not specifically assess the effects of Remimazolam and Propofol in elderly patients, individuals with cardiovascular or neurological comorbidities, or other high-risk populations. Given that different patient groups may exhibit varying responses to anesthesia, future studies should include stratified analyses to enhance the applicability of the findings to a broader range of patients.

Fourth, this study only evaluates postoperative outcomes within the first 72 h, which limits insights into long-term complications, cognitive recovery trajectories, and overall postoperative functional outcomes. While the short-term results provide valuable initial findings, they do not capture potential delayed adverse effects, prolonged cognitive impairment, or long-term recovery trends associated with different anesthetic agents. Future studies should incorporate extended follow-up periods, ranging from weeks to months, to assess the sustained impact of Remimazolam and Propofol on cognitive function, hemodynamic stability, and overall patient recovery. The study relies solely on the Montreal Cognitive Assessment (MoCA) to evaluate postoperative cognitive function. While MoCA is a widely used screening tool, it may not comprehensively capture all aspects of cognitive impairment, particularly subtle or domain-specific deficits. Future studies should consider incorporating a broader range of neurocognitive assessments, such as the Mini-Mental State Examination (MMSE) or a battery of neuropsychological tests, to provide a more thorough evaluation of postoperative cognitive changes.

Fifth, due to the limitations of retrospective data collection, this study only conducted a simple comparison of drug dosages between the Remimazolam and Propofol groups without accounting for patient-specific metabolic variations or individualized clinical responses. Factors such as hepatic and renal function, genetic polymorphisms affecting drug metabolism, and individual anesthetic sensitivity were not considered, which could influence the observed drug consumption patterns. Future research should aim to incorporate pharmacokinetic and pharmacodynamic analyses to better understand individualized responses to these anesthetic agents.

Finally, while this study focuses on general anesthesia combined with regional nerve block, the results may not be directly applicable to other anesthesia techniques, such as monitored anesthesia care or sedation in critically ill patients. Further research is needed to explore the efficacy and safety of these agents in different clinical settings.

Conclusion and future directions

In conclusion, Remimazolam offers several advantages over Propofol, including superior cognitive recovery, faster recovery times, and more stable hemodynamics, particularly in high-risk patients. Although it requires higher drug consumption, its rapid metabolism and fewer cardiovascular side effects make it a promising alternative to Propofol, especially in outpatient procedures and for elderly or high-risk patients.

Future studies with larger sample sizes, longer follow-up periods, and a focus on cost-effectiveness are needed to confirm these findings. Furthermore, additional research on optimal dosing regimens and combination therapies for Remimazolam will be essential in maximizing its clinical benefits and understanding its role in anesthesia practice.

Abbreviations

GA	General Anesthesia
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
HR	Heart Rate
MAP	Mean Arterial Pressure
POCD	Postoperative Cognitive Dysfunction
PACU	Post Anesthesia Care Unit
ASA	American Society of Anesthesiologists
BMI	Body Mass Index
POCD-24 h	Postoperative Cognitive Dysfunction at 24 h
POCD-48 h	Postoperative Cognitive Dysfunction at 48 h
POCD-72 h	Postoperative Cognitive Dysfunction at 72 h
IRB	Institutional Review Board
IRBSCDCC	Institutional Review Board of the Sichuan Provincial Disease Control Center
IRBZYCH	Institutional Review Board of Ziyang Central Hospital

Acknowledgements

We would like to thank the Sichuan Provincial Disease Control Center for providing access to the data used in this study. We also express our sincere gratitude to the Institutional Review Board of Ziyang Central Hospital for their approval and support throughout this research. Special thanks to all the patients who participated in this study and provided their consent, making this research possible. Additionally, we acknowledge the invaluable contributions of our colleagues at the research team, whose efforts were critical to the successful completion of this project. Finally, we are grateful for the financial support from the Sichuan Medical Association (SC202402) and the guidance of our mentors throughout the study.

Author contributions

Jiaman Li completed data collection, analysis, and manuscript preparation. Liao Li, Chunyi Shao, Yifeng Yang, Yan Tang, Wei Qiang, and Li Xu provided

assistance with manuscript preparation. All authors agreed to submit the article to the BMC Anesthesiology journal.

Funding
This study was supported by funding from the Sichuan Medical Association (Project No. SC202402). The funding recipient was Jiaman Li.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was conducted in full compliance with the ethical principles outlined in the Declaration of Helsinki (World Medical Association, 2013). Ethical approval was granted by the Institutional Review Boards (IRBs) of the Sichuan Provincial Disease Control Center (IRB approval number: 2015-SCDCC-078) and Ziyang Central Hospital (IRB approval number: 2019 – 185). As this was a retrospective cohort study, it was not registered in any clinical trial registry. Informed consent was obtained from all participants prior to their inclusion in the study. Written informed consent was provided by each participant, acknowledging their understanding of the study procedures, the voluntary nature of participation, and the use of their medical data for research purposes. All patient data were handled in accordance with strict confidentiality guidelines to ensure privacy and anonymity.

Consent for publication
Not applicable. This study does not contain any identifiable images or personal data that could impact the anonymity of the participants.

Competing interests
The authors declare no competing interests.

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Received: 9 December 2024 / Accepted: 19 February 2025
Published online: 15 March 2025

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