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Original Article

Hypotension incidence comparison between remimazolam and propofol in hypertensive patients undergoing spinal surgery

Jing Cui, Xinyu Qi, Junjie Wang, Lan Yao

Department of Anesthesiology, Peking University International Hospital, Beijing 102206, China

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Abstract: Objectives: This study aimed to compare the incidence of hypotension between remimazolam and propofol in hypertensive patients undergoing spinal surgery. Methods: We conducted a retrospective analysis of 194 hypertensive patients who received either remimazolam (n=99) or propofol (n=95) as the primary anesthetic during spinal surgery under general anesthesia. Hemodynamic parameters and bispectral index (BIS) were continuously monitored. The primary outcome was the incidence of intraoperative hypotension, defined as a mean arterial pressure (MAP) below 80% of baseline within 13 minutes of drug administration. Severe hypotension was defined as MAP below 70% of baseline. Postoperative adverse events, including postoperative nausea and vomiting (PONV), injection pain, dizziness, delirium, and hypoxemia, were also recorded. Results: The incidence of hypotension was significantly lower in the remimazolam group compared to the propofol group (82.83% vs. 93.68%, P=0.019). The remimazolam group demonstrated more stable MAP at key time points (5-12 minutes post-induction) and a lower incidence of PONV (15.15% vs. 29.47%, P=0.016) and injection pain (2.02% vs. 26.32%, P<0.001). Multivariate logistic regression identified remimazolam as an independent protective factor against hypotension (odds ratio [OR] =0.435, 95% confidence interval [CI]: 0.210-0.901, P=0.025). Conclusions: For hypertensive patients undergoing spinal surgery, remimazolam is associated with a significantly lower risk of intraoperative hypotension and fewer adverse events compared to propofol, suggesting it may be a safer anesthetic option for this population.

Keywords: Spinal surgery, hypotension, remimazolam, propofol

Introduction

Hypertension is a common clinical condition. For patients with hypertension who require spinal surgery, it is crucial to maintain stable blood pressure during the procedure [1]. Stable blood pressure helps reduce complications and facilitates a smoother postoperative recovery [2]. As an intravenous anesthetic agent, propofol has rapid onset and short duration of action. It is commonly used for the induction and maintenance of general anesthesia [3]. Propofol is however, prone to causing vasodilation. This can lead to a drop in blood pressure during surgery. This is particularly significant for hypertensive patients. The medical community is actively conducting clinical studies on alternative anesthetic methods with the hope of providing more stable hemodynamic support during surgery [4].

Remimazolam is a relatively new benzodiazepine drug. Due to its favorable pharmacological properties, its clinical application has gradually increased [5]. Remimazolam has a weaker vasodilatory effect and a more easily controlled metabolic process compared to propofol. This helps maintain a more stable hemodynamic state during anesthesia [6]. Its metabolism primarily relies on tissue esterases rather than the liver pathway. This makes it take effect faster and reverse more easily. These characteristics facilitate the precise adjustment of dosage by physicians and reduce the risk of long-term sedation after surgery [7]. Considering these advantages, remimazolam can be viewed as an ideal alternative to propofol. It is particularly suitable for patients with higher risks such as hypertension [8]. Therefore, when selecting a safer anesthesia protocol for such patients, a systematic comparison of the effects and safe-

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ty profiles of different anesthetics becomes particularly important [9].

Spinal surgery includes lumbar, cervical, or thoracic spine surgeries to treat degenerative intervertebral discs, spinal stenosis, or vertebral fractures, etc. In this type of surgery, maintaining blood pressure stability is critical, ensuring that the spinal cord tissue receives adequate blood flow, thus avoiding the associated complications of insufficient blood flow [10]. Patients with hypertension are more likely to experience hypotension during surgery because the ability to regulate blood vessels is reduced, and the control function of the autonomic nerve for blood pressure is reduced [11]. Therefore, when choosing anesthesia drugs, special attention should be paid to the stabilizing effect on blood pressure and heart rate, which is of great significance for promoting postoperative recovery of patients.

The incidence of hypotension during surgery often depends on the choice of anesthesia drug and the patient's own health. Studies have shown that propofol is more likely to cause hypotension, especially in older and hypertension patients [12, 13]. Therefore, it is necessary to explore new anesthetic agents such as remimazolam in order to maintain the stability of cardiovascular system. This study focused on the effect of remimazolam on the occurrence of hypotension during spinal surgery in patients with hypertension. This research direction meets the actual clinical needs and has a certain practical significance and application potential. By comparing the differences in the incidence of hypotension between remimazolam and propofol, this study hopes to provide a reference for the selection of anesthetic agents for spinal surgery in patients with hypertension. Ultimately, the results will help physicians develop safer and more individualized anesthesia regimens that will help patients recover better and increase their satisfaction with the treatment process.

Materials and methods

Study subjects

We included 194 hypertensive patients who underwent spinal surgery at Peking University International Hospital between April 2023 and March 2025 for this retrospective analysis. These patients are aged 19 to 80 years old and underwent spinal surgeries such as lumbar, cervical, or thoracic spine under general anesthesia. All patients met the diagnostic criteria for hypertension [14], and their physical condition (PS) was classified as grade II to III by the American Society of Anesthesiologists (ASA) [15], with complete medical records. Exclusion criteria include: a history of mental illness, long-term use of sedatives or antidepressants, organic heart disease other than hypertension, liver failure or cirrhosis, and patients with elevated intracranial pressure.

Patients were divided into the propofol group (n=95) and the remimazolam group (n=99) based on the primary anesthetic drug used during surgery. The propofol group was defined as patients who received propofol as the primary anesthetic agent, while the remimazolam group was defined as those who received remimazolam as the primary anesthetic agent.

Data collection and ethics statement

Patient data, including general data, incidence of intraoperative hypotension under anesthesia, hemodynamic parameters, and anesthesia depth indicators, were collected through the medical record system. This single-center, retrospective study was conducted in accordance with the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board (IRB) of Peking University International Hospital. Given the retrospective nature of the study, which involved the analysis of anonymized data extracted from electronic medical records, the IRB granted a waiver of informed consent.

Anesthesia process

Upon entering the operating room, patients were immediately monitored for pulse oximetry (Rainbow sensor, Masimo Corp., USA), noninvasive blood pressure (NIBP) measurement (Patient Monitor iPM 12, Shenzhen Mindray Biomedical Electronics Co., Ltd., China), electrocardiography (PageWriter TC50, Philips, Netherlands), and bispectral index (BIS) monitoring (LoC 2 Channel BIS monitor, COVIDIEN, USA). Additionally, after administration of sedatives, systolic blood pressure, diastolic blood pressure, mean blood pressure (MBP), and heart rate (HR) were recorded every minute.

Prior to infusion of remifentanil + remimazolam/propofol via a medical syringe pump (Agillia, SB Medica SRL, Italy), patients were administered 1 mg of penehyclidine hydrochloride injection (Approval No. TWK24105, Jiangsu Nhwa Pharmaceutical Co., Ltd., Jiangsu Province, China).

In the remimazolam group, anesthesia induction was performed using intravenous remifentanil hydrochloride (Approval No. H20030197, Yichang Renfu Pharmaceutical Co., Ltd., Hubei Province, China) with an effect-site concentration of 4.0 ng/mL (target-controlled infusion [TCI], Minto model) and intravenous remimazolam besylate (Approval No. H20200006, Yichang Renfu Pharmaceutical Co., Ltd., Hubei Province, China) at an infusion rate of 6 mg/kg/h. In the propofol group, anesthesia induction was performed using propofol emulsion injection (Approval No. HJ20150657, Fresenius Kabi Deutschland GmbH, Austria) (TCI, Schneider model) and intravenous remifentanil hydrochloride (same as in the remimazolam group) at effect-site concentrations of 4.0 μg/mL and 4.0 ng/mL, respectively. Once loss of consciousness was achieved and the BIS decreased to 40-60, both groups received intravenous rocuronium bromide (Approval No. H20093186, Zhejiang Xianju Pharmaceuticals Co., Ltd., Zhejiang Province, China) at a dose of 0.6 mg/kg to induce neuromuscular blockade, followed by endotracheal intubation after adequate muscle relaxation. During the maintenance phase of anesthesia, the infusion rates of propofol (2.0-3.0 μg/mL) and remimazolam (1-2 mg/kg/h) were adjusted to maintain the BIS between 40 and 60, ensuring an appropriate level of anesthesia depth.

Definition of hypotension and management

In this study, the observation window for hypotension was defined as the period from 0 to 13 minutes after the initiation of remimazolam/propofol administration. This time window also covers the critical period from the start of anesthesia induction to the beginning of surgical incision (refer to the start time of incision recorded in **Table 2**; in this study, the incision start times for both groups were concentrated between 13.31 and 13.45 minutes after drug administration), allowing for the complete capture of early blood pressure fluctuations associated with the drugs. Hypotension was defined as a mean blood pressure (MBP) less than 80% of the baseline MBP (recorded before the initiation of anesthesia infusion) within 13 minutes of starting remimazolam or propofol administration. Severe hypotension was defined as a MAP less than 70% of the baseline MBP [16, 17]. Hypotension was treated by reducing the infusion rate of remifentanil, while severe hypotension was managed with an injection of 8 mg ephedrine hydrochloride (Approval No. H21022412, Northeast Pharmaceutical Group Shenyang First Pharmaceutical Co., Ltd., Liaoning Province, China).

Outcome assessment

The primary outcome measure of this study was the incidence of hypotension and severe hypotension under anesthesia. As secondary outcomes, we also analyzed hemodynamic parameters (MAP and HR) and BIS, which were assessed at baseline (before administration of sedative drugs in the operating room) and from 0 minutes (at the start of drug administration) to 13 minutes (13 minutes after the administration of sedative drugs). Postoperative adverse events were also evaluated, including postoperative nausea and vomiting (PONV), dizziness, delirium, injection pain, and postoperative hypoxemia with peripheral oxygen saturation (SpO_2) <90%.

Statistical analysis

Data analysis was performed using SPSS statistical software (version 29.0; developed by SPSS Inc., Chicago, IL, USA). Continuous variables that followed a normal distribution were expressed as mean ± standard deviation (M ± SD) and compared between groups using independent samples t-tests. Categorical variables were expressed as frequencies and percentages [n (%)] and compared between groups using the χ^2 test. A *p*-value less than 0.05 was considered statistically significant. Subsequently, with intraoperative hypotension occurrence as the dependent variable (no occurrence =0, occurrence =1), and anesthetic drug type use (propofol =0, remimazolam =1), age, body mass index (BMI), ASA PS classification (Class II =0, Class III =1), and total dose of remifentanil as potential influencing factors, univariate and multivariate logistic regression analyses were conducted to identify independent risk factors for the incidence of intraoperative hypotension

Table 1. Comparison of demographic characteristics between the two groups

Parameter	Propofol group (n=95)	Remimazolam group (n=99)	t/χ^2	P
Age (years)	63.48 ± 7.56	61.95 ± 8.63	1.308	0.193
Gender [n (%)]			0.071	0.789
Male	45 (47.37%)	45 (45.45%)		
Female	50 (52.63%)	54 (54.55%)		
BMI (kg/m^2)	24.85 ± 3.12	25.51 ± 3.45	1.393	0.165
ASA PS [n (%)]			0.344	0.557
II	85 (89.47%)	91 (91.92%)		
III	10 (10.53%)	8 (8.08%)		
Medical history [n (%)]				
Diabetes mellitus	28 (29.47%)	25 (25.25%)	0.435	0.510
Ischemic heart disease	12 (12.63%)	10 (10.10%)	0.309	0.578
Pulmonary disease	8 (8.42%)	8 (8.08%)	0.007	0.931
Renal disease	5 (5.26%)	7 (7.07%)	0.273	0.601
Antihypertensive medication use [n (%)]				
ACEI/ARB	78 (82.11%)	82 (82.83%)	0.018	0.895
CCB	75 (78.95%)	80 (80.81%)	0.105	0.746
Beta-blocker	65 (68.42%)	70 (70.71%)	0.120	0.729
Diuretics	40 (42.11%)	45 (45.45%)	0.221	0.638

Abbreviations: BMI, Body Mass Index; ASA PS, American Society of Anesthesiologists Physical Status; ACEI, Angiotensin-Converting Enzyme Inhibitor; ARB, Angiotensin Receptor Blocker; CCB, Calcium Channel Blocker.

in hypertensive patients undergoing spinal surgery.

Results

General data

The comparison of demographic characteristics between the Propofol group (n=95) and the Remimazolam group (n=99) revealed no significant differences across multiple parameters examined (**Table 1**). There were no significant differences in age (P=0.193), gender (P=0.789), BMI (P=0.165), and ASA PS (P=0.557) between the two groups of patients. Similarly, there were no significant differences in the prevalence of medical history conditions including diabetes mellitus (P=0.510), ischemic heart disease (P=0.578), pulmonary disease (P=0.931), and renal disease (P=0.601). Additionally, no significant differences were found in the use of antihypertensive medications such as angiotensin-converting enzyme inhibitor/angiotensin receptor blocker (ACEI/ARB) (P=0.895), calcium channel blocker (CCB) (P=0.746), beta-blocker (P=0.729), or diuretics (P=0.638).

There were no significant differences in the distribution of surgery types (P=0.884), anesthetic time (P=0.584), operative time (P=0.433), start time of tracheal intubation (P=0.081), or start time of skin cutting (P=0.387) (**Table 2**). Additionally, the total dose of remifentanil did not differ significantly between the groups (P=0.129). Since propofol and remimazolam were exclusively used in their respective groups, direct comparisons of their total doses were not performed.

Incidence of hypotension under anesthesia

The incidence of hypotension was significantly different between the two groups, with 89 (93.68%) patients in the Propofol group experiencing hypotension compared to 82 (82.83%) patients in the Remimazolam group (χ^2=5.467, P=0.019) (**Figure 1**). However, for severe hypotension, no significant difference was noted (P=0.086), with 73 (76.84%) patients in the Propofol group and 65 (65.66%) patients in the Remimazolam group affected.

MBP changes

For MBP changes over time, no significant differences were noted at baseline (P=0.265), 0 min (P=0.361), 1 min (P=0.214), 2 min (P=0.082), 3 min (P=0.253), 4 min (P=0.159),

Table 2. Comparison of surgery features between the two groups

Parameter	Propofol group (n=95)	Remimazolam group (n=99)	t/χ^2	P
Surgery type [n (%)]			0.247	0.884
Lumbar spine surgery	56 (58.95%)	58 (58.59%)		
Cervical spine surgery	24 (25.26%)	23 (23.23%)		
Thoracic spine surgery	15 (15.79%)	18 (18.18%)		
Anesthetic time (min)	128.72 ± 18.65	130.14 ± 17.31	0.548	0.584
Operative time (min)	117.76 ± 15.57	115.95 ± 16.42	0.785	0.433
Start time of tracheal intubation (min)	3.15 ± 0.72	3.32 ± 0.68	1.752	0.081
Start time of skin cutting (min)	13.31 ± 1.05	13.45 ± 1.19	0.867	0.387
Total dose of anesthetic drug				
Propofol (mg)	282.38 ± 43.91	-		
Remimazolam (mg)	-	19.63 ± 3.92		
Remifentanil (μg)	224.59 ± 34.05	232.82 ± 40.73	1.523	0.129

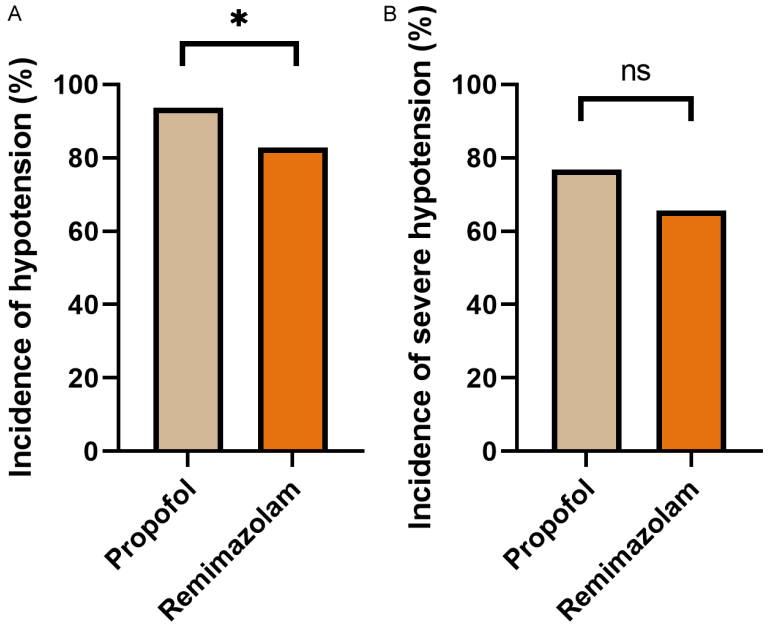

Figure 1. Comparison of incidence of hypotension under anesthesia between two groups. A. Incidence of hypotension; B. Incidence of severe hypotension. ns: no significant difference; *: P<0.05.

7 min (P=0.315), 8 min (P=0.275), or 13 min (P=0.132) (**Figure 2**). However, differences with statistical significance were observed at 5 min (93.78 ± 1.45 vs. 93.22 ± 1.52, t=2.625, P=0.009), 6 min (92.84 ± 1.32 vs. 93.26 ± 1.28, t=2.257, P=0.025), 9 min (82.43 ± 1.97 vs. 83.02 ± 1.94, t=2.109, P=0.036), 10 min (81.68 ± 1.82 vs. 82.46 ± 1.86, t=2.950, P=0.004), 11 min (80.35 ± 1.73 vs. 80.99 ± 1.79, t=2.505, P=0.013), and 12 min (78.97 ± 1.68 vs. 79.63 ± 1.71, t=2.689, P=0.008).

HR changes

For HR changes over time, there were notable differences between the two groups (**Table 3**). Specifically, HR in the remimazolam group was significantly lower at several time points, including 2 min (64.96 ± 3.84 vs. 65.99 ± 2.35, P=0.026), 5 min (71.47 ± 3.21 vs. 72.52 ± 3.16, P=0.023), 6 min (67.57 ± 2.82 vs. 68.55 ± 2.32, P=0.009), 8 min (67.95 ± 3.12 vs. 68.85 ± 2.64, P=0.030), 9 min (67.83 ± 2.54 vs. 68.96 ± 2.91, P=0.004), 10 min (67.64 ± 2.36 vs. 68.34 ± 2.05, P=0.029), 11 min (67.52 ± 2.85 vs. 68.33 ± 1.86, P=0.022), and 12 min (67.45 ± 2.48 vs. 68.36 ± 1.57, P=0.003). No statistically significant differences in HR were observed between the two groups at baseline, 0, 1, 3, 4, 7, or 13 minutes (all P>0.05).

BIS changes

For BIS changes over time, no significant differences were noted at baseline (P=0.508), 0 min (P=0.148), 1 min (P=0.365), 2 min (P=0.347), 3 min (P=0.325), 4 min (P=0.247), 5 min (P=0.122), 6 min (P=0.073), 7 min (P=0.057),

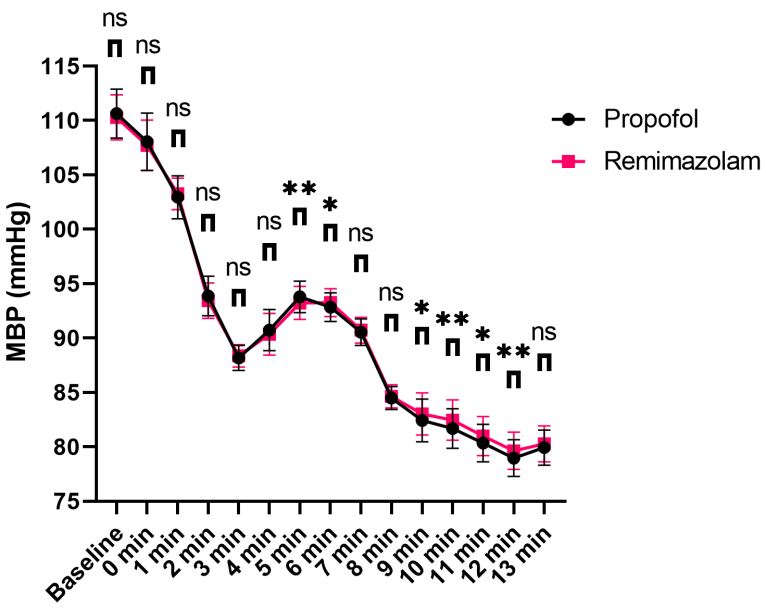

Figure 2. Comparison of MBP changes over time between two groups (mmHg). ns: no significant difference; *: P<0.05; **: P<0.01. Abbreviation: MBP, Mean Blood Pressure.

8 min (P=0.154), 10 min (P=0.445), 11 min (P=0.054), 12 min (P=0.193), or 13 min (P=0.050) (**Table 4**). However, a difference with statistical significance was observed at 9 min (44.72 ± 1.91 vs. 45.38 ± 1.83, t=2.458, P=0.015).

Postoperative adverse events

In comparing the incidence of postoperative adverse events between the Propofol group and the Remimazolam group, significant differences were observed in the occurrence of PONV (29.47% vs. 15.15%, X^2=5.764, P=0.016) and injection pain (26.32% vs. 2.02%, X^2=23.886, P<0.001) (**Table 5**). No significant differences were noted for dizziness (2.63% vs. 5.05%, X^2=3.485, P=0.062), delirium (8.42% vs. 3.03%, X^2=2.634, P=0.105), or SpO_2<90% (10.53% vs. 4.04%, X^2=3.046, P=0.081).

Univariate and multivariate logistic regression analysis

The univariate logistic regression analysis identified several factors for intraoperative hypotension in hypertensive patients undergoing spinal surgery: Remimazolam use was significantly associated with a reduced risk (odds ratio [OR]=0.429, 95% Confidence interval [CI]: 0.211-0.871, P=0.019), while age (OR=1.053, 95% CI: 1.017-1.091, P=0.034), BMI (OR=1.148, 95% CI: 1.058-1.246, P=0.031), ASA PS III classification (OR=6.507, 95% CI: 2.038-20.771, P=0.022), and total dose of remifentanil (OR=1.015, 95% CI: 1.001-1.029, P=0.032) were significantly associated with an increased risk (**Table 6**).

The multivariate logistic regression analysis identified that remimazolam use was a significant protective factor (OR=0.435, 95% CI: 0.210-0.901, P=0.025), while age (OR=1.049, 95% CI: 1.011-1.089, P=0.042), BMI (OR=1.133, 95% CI: 1.039-1.236, P=0.045), ASA PS III classification (OR=5.166, 95% CI: 1.547-17.253, P=0.038), and total dose of remifentanil (OR=1.014, 95% CI: 1.008-1.028, P=0.045) were significant risk factors (**Table 7**). These findings indicate that Remimazolam use is an important protective factor against intraoperative hypotension, whereas older age, higher BMI, ASA PS III classification, and a higher total dose of remifentanil are associated with an increased risk of intraoperative hypotension.

Discussion

The primary finding of this study - a significantly lower incidence of intraoperative hypotension in hypertensive patients receiving remimazolam compared to those receiving propofol during spinal surgery - can be critically explained by the distinct hemodynamic profiles of the two anesthetic agents in the context of the impaired cardiovascular compensatory mechanisms inherent to hypertension. While both propofol and remimazolam act via gamma aminobutyric acid type A (GABA-A) receptors, their cardiovascular effects diverge substantially. Propofol induces pronounced vasodilation through direct effects on vascular smooth muscle and inhibition of sympathetic vasoconstrictor tone, leading to a significant decrease in systemic vascular resistance and blood pressure [18]. This effect is particularly problematic for hypertensive patients, who often exhibit

Table 3. Comparison of HR changes over time between the two groups (beats/min)

Parameter	Propofol group (n=95)	Remimazolam group (n=99)	T	P
Baseline	71.09 ± 3.65	71.62 ± 3.48	1.036	0.301
0 min	68.55 ± 2.57	68.83 ± 3.35	0.648	0.518
1 min	65.23 ± 2.46	65.54 ± 2.74	0.841	0.401
2 min	64.96 ± 3.84	65.99 ± 2.35	2.242	0.026
3 min	67.68 ± 3.83	68.56 ± 2.96	1.786	0.076
4 min	71.52 ± 4.18	72.31 ± 3.04	1.501	0.135
5 min	71.47 ± 3.21	72.52 ± 3.16	2.300	0.023
6 min	67.57 ± 2.82	68.55 ± 2.32	2.642	0.009
7 min	67.78 ± 2.74	68.36 ± 2.08	1.645	0.102
8 min	67.95 ± 3.12	68.85 ± 2.64	2.180	0.030
9 min	67.83 ± 2.54	68.96 ± 2.91	2.887	0.004
10 min	67.64 ± 2.36	68.34 ± 2.05	2.198	0.029
11 min	67.52 ± 2.85	68.33 ± 1.86	2.312	0.022
12 min	67.45 ± 2.48	68.36 ± 1.57	3.059	0.003
13 min	71.09 ± 3.65	71.62 ± 3.48	1.036	0.301

Abbreviation: HR, Heart Rate.

Table 4. Comparison of BIS changes over time between the two groups

Parameter	Propofol group (n=95)	Remimazolam group (n=99)	t	P
Baseline	96.70 ± 0.87	96.62 ± 0.85	0.664	0.508
0 min	94.22 ± 1.24	94.47 ± 1.18	1.454	0.148
1 min	84.95 ± 2.63	85.28 ± 2.41	0.908	0.365
2 min	72.79 ± 2.75	73.14 ± 2.38	0.943	0.347
3 min	62.86 ± 2.54	63.21 ± 2.32	0.986	0.325
4 min	54.82 ± 1.95	55.13 ± 1.83	1.162	0.247
5 min	49.37 ± 1.92	49.78 ± 1.78	1.552	0.122
6 min	46.84 ± 1.76	47.28 ± 1.65	1.803	0.073
7 min	45.63 ± 2.05	46.19 ± 1.98	1.915	0.057
8 min	45.28 ± 1.97	45.67 ± 1.85	1.430	0.154
9 min	44.72 ± 1.91	45.38 ± 1.83	2.458	0.015
10 min	45.05 ± 1.86	45.26 ± 1.89	0.765	0.445
11 min	44.51 ± 1.74	44.99 ± 1.76	1.938	0.054
12 min	44.49 ± 1.65	44.80 ± 1.64	1.308	0.193
13 min	44.31 ± 1.41	44.72 ± 1.45	1.972	0.050

Abbreviation: BIS, Bispectral Index.

Table 5. Comparison of postoperative adverse events between the two groups [n (%)]

Parameter	Propofol group (n=95)	Remimazolam group (n=99)	X^2	P
PONV	28 (29.47%)	15 (15.15%)	5.764	0.016
Dizziness	12 (12.63%)	5 (5.05%)	3.485	0.062
Delirium	8 (8.42%)	3 (3.03%)	2.634	0.105
Injection pain	25 (26.32%)	2 (2.02%)	23.886	<0.001
SpO_2<90%	10 (10.53%)	4 (4.04%)	3.046	0.081

Abbreviation: PONV, Post Operative Nausea and Vomiting; SpO_2, Peripheral Oxygen Saturation.

Table 6. Univariate logistic regression analysis of risk factors for the incidence of intraoperative hypotension in hypertensive patients undergoing spinal surgery

Parameters	Coefficient	Std Error	Wald	P	OR	95% CI
Remimazolam use	-0.847	0.362	5.472	0.019	0.429	0.211-0.871
Age	0.052	0.018	8.352	0.034	1.053	1.017-1.091
BMI	0.138	0.042	10.782	0.031	1.148	1.058-1.246
ASA PS III	1.873	0.592	10.005	0.022	6.507	2.038-20.771
Total dose of remifentanil	0.015	0.007	4.592	0.032	1.015	1.001-1.029

Abbreviations: OR, Odds Ratio; CI, Confidence Interval; BMI, Body Mass Index; ASA PS, American Society of Anesthesiologists Physical Status.

Table 7. Multivariate logistic regression analysis of risk factors for the incidence of intraoperative hypotension in hypertensive patients undergoing spinal surgery

Parameters	Coefficient	Std Error	Wald Stat	P	OR	OR CI Lower	OR CI Upper
Remimazolam use	-0.832	0.371	5.028	0.025	0.435	0.210	0.901
Age	0.048	0.019	6.382	0.042	1.049	1.011	1.089
BMI	0.125	0.044	8.062	0.045	1.133	1.039	1.236
ASA PS III	1.642	0.615	7.123	0.038	5.166	1.547	17.253
Total dose of remifentanil	0.014	0.007	4.001	0.045	1.014	1.008	1.028

Abbreviations: OR, Odds Ratio; CI, Confidence Interval; BMI, Body Mass Index; ASA PS, American Society of Anesthesiologists Physical Status.

impaired baroreflex sensitivity and reset autoregulation of vital organ perfusion [11, 19]. Their circulatory system is less capable of compensating for rapid decreases in blood pressure, making them highly susceptible to hypotensive episodes under propofol anesthesia. In contrast, remimazolam demonstrates a more favorable hemodynamic profile characterized by minimal effects on systemic vascular resistance [20, 21]. The more stable blood pressure observed in the remimazolam group, especially during the critical induction period captured in our data, suggests a significantly reduced challenge to the already compromised compensatory reserves of hypertensive patients. This pharmacological characteristic is crucial for maintaining adequate perfusion pressure to the spinal cord during surgery, an organ highly vulnerable to ischemic injury when blood pressure falls below its autoregulatory threshold [10]. Therefore, the lower hypotension incidence with remimazolam is not merely a reflection of a different mechanism of action but underscores its potential as a safer anesthetic choice for patients with compromised vascular autoregulation, such as those with chronic hypertension [6, 22].

According to MAP analysis, there was a significant difference in blood pressure between the two groups during the critical period of 5 to 12 minutes after induction of anesthesia. This result suggests that remimazolam may help maintain smoother blood pressure levels during the critical period of anesthesia [23]. The cause of this phenomenon may be related to differences in pharmacokinetics and pharmacodynamics of the two drugs [24]. Remimazolam has a quick start, quick clearing and short half-life, which allows doctors to more precisely adjust the dose to better control blood pressure [25]. The drug is metabolized primarily through tissue esterases, which are widely present in the body, and is not dependent on the liver enzyme chain, so drug-drug interactions are fewer and the effect on hemodynamic regulation is more controllable and predictable [22]. The action time of propofol is longer, the dilation of blood vessels is also more significant, and it is easier to cause significant fluctuations in blood pressure. This is particularly alarming in hypertensive individuals, who often have impaired vascular regulation and autonomic nervous system response [19]. For these patients, the use of remimazolam may help to reduce blood pressure fluctuations and thus maintain a more stable hemodynamic state during surgery.

During the observation period, there were indeed differences in the changes in HR between the two groups of patients. HR in the

remimazolam group was generally lower at multiple time points during anesthesia. This result aligns with the pharmacological properties of remimazolam. It is less likely to induce reflex tachycardia compared to propofol. Reflex tachycardia typically occurs as a response to the body's attempt to compensate for hypotension resulting from vasodilation. Remimazolam has a relatively low incidence of related adverse reactions in clinical use. Remimazolam has shown significant advantages in maintaining cardiovascular stability. Research indicates that it may be more effective than propofol in regulating sympathetic nerve activity [26]. Its action mechanism includes the inhibition of reflex tachycardia and maintenance of a stable HR. This stability is particularly important for hypertensive populations. As they often require maintaining adequate cardiac output and tissue perfusion [27].

A meta-analysis by Pereira et al. [28] corroborates the findings of this study. It indicates that remimazolam is more effective than propofol in reducing the risk of hypotension during surgery in elderly patients. Peng et al. [28] also observed that remimazolam provided more stable blood pressure and HR during general anesthesia induction. These outcomes align with what we recorded. Such consistency suggests that remimazolam has better hemodynamic stability. It may be especially useful for hypertensive patients receiving spinal surgery.

It is important to maintain consistency in the depth of anesthesia when comparing the hemodynamic effects of different anesthetic drugs [29]. If there is a significant difference in anesthesia depth, blood pressure changes may be due to depth differences rather than drug characteristics [30]. This study confirmed that the remimazolam group and propofol group were at the same level of anesthesia depth at most time points through strict monitoring of the BIS (maintained between 40-60). This discovery enables the observed differences in the incidence of hypotension and significant changes in MBP at key time points to be more confidently attributed to the milder hemodynamic inhibitory effect of remimazole, rather than other confounding factors. Although the BIS values of the two groups are generally similar, the subtle differences observed at the 9th minute are worth exploring. At this time, the BIS value of the remimazolam group was slightly higher, and MBP was significantly higher than that of the propofol group. This phenomenon may indicate that while achieving similar sedative effects (within the BIS target range), remimazolam has a weaker inhibitory effect on the cardiovascular system than propofol. Remimazolam does not deeply suppress the central nervous system as propofol does, while it does produce adequate anesthetic effects. This characteristic is highly consistent with its stable hemodynamic performance. It can maintain a stable cardiovascular function while ensuring an appropriate anesthesia depth. Remimazolam achieves a good balance between the depth of sedation and the stability of the circulatory system.

Postoperative adverse events revealed that remimazolam significantly reduced the occurrence of PONV and injection pain among patients with hypertension undergoing spinal surgery. The incidence of other adverse reactions also showed a downward trend. This effect aligns with its pharmacological properties [31]. Therefore, remimazolam can be considered as a safer anesthetic option for this patient population. It may help reduce problems after surgery and support better recovery.

Results from univariate and multivariate logistic regression analysis further supported previous findings. Even after controlling for confounding factors such as age, BMI, and ASA grade, remimazolam showed an independent protective effect on intraoperative hypotension. On the premise that the monitoring of BIS confirms the same depth of anesthesia, the above analysis results go beyond the simple comparison between groups, and can provide reference for clinical decision-making. Results showed that for patients with hypertension undergoing spinal surgery, especially those at high risk of hypotension (e.g., elderly or high BMI), the use of remimazolam as an alternative to propofol can be seen as a positive and effective risk management measure to help reduce the risk of hypotension and related complications during surgery.

This study has certain limitations. Although the sample size meets the requirements of the research design, it may still not be sufficient to comprehensively reflect the differences in response among different patient subgroups. In the future, we need to conduct a multi-cen-

ter, large-scale study to validate the current findings and further explore the benefits of remimazolam in long-term clinical use. Our research primarily focuses on patients who have undergone spinal surgery. It is not yet clear whether these results apply to other types of surgeries. We need to further evaluate the efficacy and safety of remimazolam in a broader range of surgical procedures. The study also identified some risk factors associated with intraoperative hypotension. Yet the specific mechanisms underlying these factors remain unclear. It is essential to delve deeper into these mechanisms in the future to lay the groundwork for developing more precise risk management strategies. In addition, this study primarily focuses on the induction phase, and future research needs to prospectively design studies covering the maintenance, emergence, and post-anesthesia care unit [PACU] phases to verify the long-term hemodynamic stability of remimazolam. Finally, although statistically significant differences in MAP and HR were observed at multiple time points, the absolute differences were very small. The individual clinical relevance of these differences at each isolated moment may be limited. Therefore, the clinical significance of these differences is minimal, and they should not be over-interpreted. The primary clinical value of these data lies in their collective demonstration of more stable hemodynamic trends associated with remimazolam, which aligns with the clinically significant reduction in the incidence of hypotension. The clinical relevance of the minor differences in MAP and HR detected in this study needs to be further validated in prospective studies using more direct clinical endpoints.

Despite the aforementioned limitations, this study still holds significant clinical reference value. In hypertensive patients, a group often characterized by compromised cardiovascular compensatory mechanisms, even minor fluctuations in blood pressure can lead to inadequate organ perfusion, especially in contexts requiring high blood pressure stability, such as spinal surgery. The overall lower incidence of hypotension and more stable hemodynamic trends observed with remimazolam suggest that it may provide a broader safety margin for high-risk patients in clinical practice. Additionally, remimazolam's notable advantages in reducing injection pain and postoperative nausea and vomiting further support its rationale as an alternative to propofol, particularly for patients sensitive to blood pressure fluctuations or at risk of adverse drug reactions. This study provides preliminary data supporting more refined anesthesia drug selection strategies and underscores the importance of individualized anesthesia management in hypertensive patient populations.

Conclusion

Among patients with hypertension undergoing spinal surgery, remimazolam is more effective than propofol in reducing the risk of intraoperative hypotension. It helps maintain the stability of hemodynamic parameters. Multivariate analysis further confirms that remimazolam is an independent protective factor for preventing intraoperative hypotension. Remimazolam may offer a safer option when selecting an anesthesia regimen for such surgeries. However, these conclusions still need to be validated through larger-scale studies. This will provide more compelling evidence for its application in a broader range of clinical scenarios.

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Disclosure of conflict of interest

None.

Address correspondence to: Lan Yao, Department of Anesthesiology, Peking University International Hospital, No. 1 Life Park Road, Zhongguancun Life Science Park, Changping District, Beijing 102206, China. E-mail: 1508yaolan@sina.com

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