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ARTICLE

Effects of General Anesthesia Induced by Remimazolam and Propofol on Adverse and Inflammatory Reactions in Patients After Colorectal Cancer Surgery: A Retrospective Study

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Abstract

Aims/Background Globally, colorectal cancer ranks as the third most common malignant tumor. This study aims to evaluate and compare the effects of remimazolam versus propofol in patients undergoing surgical treatment for colorectal cancer.

Methods This study retrospectively analyzed 160 patients who underwent colorectal cancer surgery from January 2023 to December 2024 at the First People's Hospital of Xiaoshan District. Seventy-five patients receiving propofol anesthesia were classified in the control group, whereas 85 patients anesthesized with remimazolam were categorized in the study group. Anesthesia index levels, recovery quality (Riker sedation-agitation scale [SAS] and confusion assessment method-Chinese revision [CAM-CR]), mean arterial pressure (MAP), heart rate (HR), adverse effects and levels of inflammatory factors, such as interleukin (IL)-6, IL-8, tumor necrosis factor alpha (TNF-α), were analyzed using chi-squared test and *t*-tests.

Results In the study group, the time to anesthesia onset, recovery duration, length of stay in the post-anesthesia care unit (PACU), as well as the SAS and CAM-CR scores, were significantly shorter compared to those in the control group ($p < 0.05$). At 3 min before anesthesia (T1), there were no differences in MAP and heart rate levels between the two groups ($p > 0.05$). At 30 min after anesthesia (T2), immediately after surgery (T3), and 5 min after surgery (T4), the MAP of the study group exceeded those observed in the control group ($p < 0.05$). The incidence of adverse reactions in the study group was 10.59% (9/85), which was significantly lower than that in the control group (37.33% (28/75)) ($p < 0.05$). Furthermore, during the same postoperative period, levels of IL-6, IL-8, and TNF-α were found to be reduced in the study group compared to the control group ($p < 0.05$).

Conclusion Remimazolam outperforms propofol in inducing general anesthesia for patients undergoing colorectal cancer surgery, evidenced by improvement in recovery quality and hemodynamic level, as well as reduction in the incidence of adverse effects and inflammatory level.

Key words: remimazolam; propofol; colorectal cancer; recovery quality; hemodynamics; adverse reaction

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Introduction

Colorectal cancer, which encompasses both colon and rectal cancer, stands as one of the most prevalent malignant tumors in humans (Archambault et al, 2020; Thomas et al, 2020). Morbidity attributed to colorectal cancer is on the rise worldwide; however, misdiagnosis for this cancer is common, and less than 40% of cases

diagnosed in early stages have metastasized by the time they are diagnosed (van de Velde, 2015). At present, surgery and postoperative radiotherapy are the recognized approaches to treating colorectal cancer, with the surgical approach being the primary means of treatment. Patients in the perioperative stage may suffer from decreased immune function, hemodynamic changes, adverse reactions and inflammatory reactions due to various factors such as anesthesia, pain and blood loss, and body dysfunction induced by inflammation, which may affect the progress of postoperative recovery. Study has shown that rational anesthesia can minimize the impact on patient's hemodynamic indices and reduce the occurrence of complications (Tang et al, 2024).

General anesthesia is recognized for several advantages, such as ease of deployment, immediate onset of action, and apparent analgesic effect, but such effect varies with the anesthetic drugs given (Goel et al, 2020; Gao et al, 2024). Propofol and remimazolam are anesthetic agents commonly used in clinical settings; propofol belongs to the alkylate class of anesthetics that act upon the central nervous system, while remimazolam belongs to the novel, ultra-short-acting benzodiazepine class of sedative drugs (Wu et al, 2023). Earlier research indicates that propofol is commonly used in the induction and maintenance of general anesthesia, but the users are prone to respiratory depression, circulatory fluctuations and other symptoms, and prolonged high-dose infusion can lead to propofol infusion syndrome (Krajčová et al, 2015; Zeng et al, 2024). The current research hotspot in the field of anesthesia is searching for high-efficacy anesthetics with a low incidence rate of adverse events. Through investigations, remimazolam is a newly identified type of ultra-short-acting sedative that does not rely on hepatic and renal metabolism. Study has reported that remimazolam acts on γ-aminobutyric acid A ($GABA_A$) receptors, has a rapid onset of action, and does not have a cumulative effect (Kim, 2022). Existing studies demonstrate the gradual adoption of remimazolam into the routine practice for the induction and maintenance of anesthesia. In a clinical trial of general anesthesia for surgery, a satisfactory depth of anesthetic sedation was achieved in healthy subjects by induction with 0.25 mg/kg/min of remimazolam and maintenance with 1 mg/kg/h of remimazolam (Sheng et al, 2020). However, few studies have investigated the effects of general anesthesia with remimazolam and propofol on adverse events occurring in the postoperative period for colorectal cancer patients.

The present study was conducted to compare the clinical efficacy and safety of remimazolam and propofol in patients undergoing colorectal cancer surgery by retrospectively analyzing their inflammatory indices and postoperative recovery.

Methods

Research Design

This study retrospectively analyzed the clinical data of 160 patients undergoing radical surgery for colorectal cancer from January 2023 to December 2024 in the First People's Hospital of Xiaoshan District. The inclusion criteria of this study are as follows: (1) patients identified as having colorectal cancer through diagnostic

evaluation; (2) patients aged 50–65 years; (3) patients with indications for surgical treatment; and (4) patients with comprehensive set of clinical information. Patients fulfilling the following criteria are excluded: (1) history of thrombotic events; (2) severe hepatic or renal insufficiency; (3) hypertension, diabetes, psychiatric, cardiovascular, or respiratory disorders; (4) incomplete clinical data; and (5) allergy to anesthetic agents. A careful alignment to the predefined criteria resulted in the inclusion of 160 patients for the study (Fig. 1). Seventy-five patients receiving propofol anesthesia were classified in the control group, whereas 85 patients anesthesized with remimazolam were categorized in the study group.

This study has been approved by the Ethics Review Committee of the First People's Hospital of Xiaoshan District (No. 2025-11). The present study was conducted in strict adherence to the Declaration of Helsinki. Informed consent was obtained by all patients included in this study.

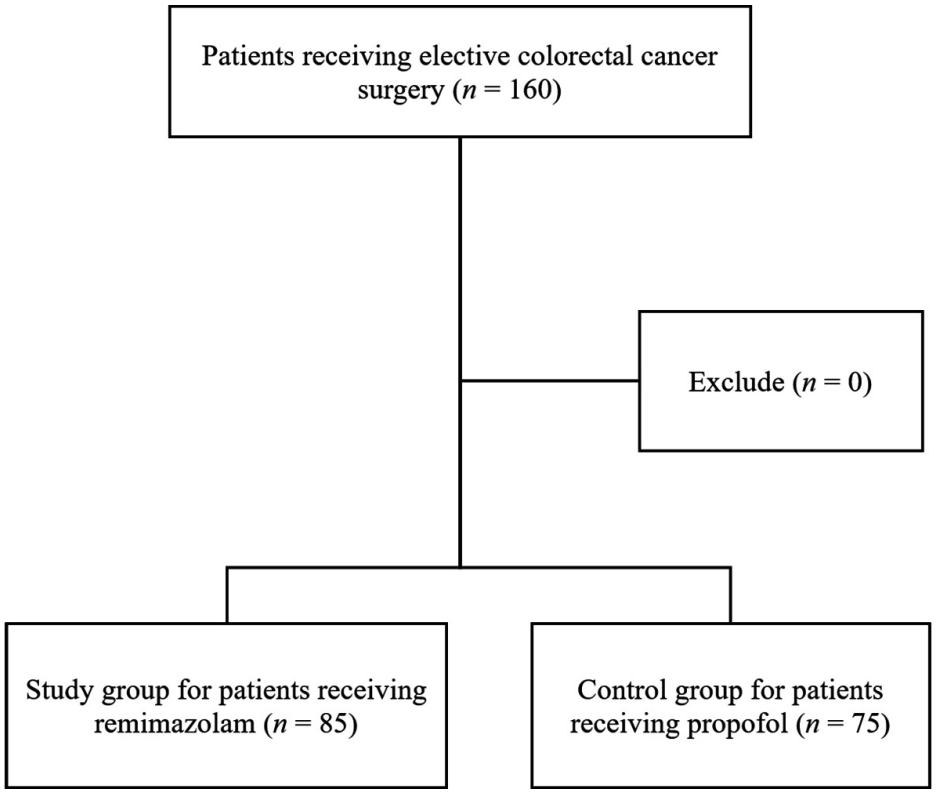

Fig. 1. Schematic representation outlining the patient selection process for this retrospective analysis.

Induction and Maintenance of Anesthesia

In both groups, 8 h of preoperative abstinence from drinking and 12 h of abstinence from eating were imposed, and venous access was established after entering the operating room. To induce anesthesia, subjects in the control group was injected with propofol medium/long-chain fat milk injection (China National Pharmaceutical License H20143235, 50 mL: 0.5 g, Sichuan Guorui Pharmaceutical Co., Ltd., Chengdu, China) at 2 mg/kg, sufentanil citrate injection (State Pharmaceuti-

cal License H20054171, 1 mL: 50 μg, Hubei Yichang Renfu Pharmaceutical Co., Ltd., Yichang, China) at 0.3 μg/kg, and cisatracurium besilate (State Pharmaceutical License H20223612, 10 mg, Zhejiang Xianju Pharmaceutical Co., Ltd., Taizhou, China) at 0.2 mg/kg. For the study group, the subjects were injected intravenously with remimazolam mesylate (State Drug License No. H20190034, 36 mg, Jiangsu Hengrui Pharmaceutical Co., Ltd., Lianyungang, China) at 0.2 mg/kg, sufentanil citrate injection at 0.3 μg/kg, and cisatracurium besilate at 0.2 mg/kg.

To maintain anesthesia, subjects in the control group received intravenous infusion of propofol medium/long-chain fat milk injection at 4–10 mg/kg/h, remifentanil hydrochloride (Sinopharm Group Industry Co., Ltd., State Drug License H2012 3421, 1 mg) at 0.1–0.2 μg/kg/min. The subjects in the study group were intravenously infused with remimazolam mesylate at 0.4–1.2 mg/kg/h and remifentanil hydrochloride at 0.1–0.2 g/kg/min. During surgery, bispectral index (BIS) values were recorded every 5 minutes, and if they exceeded the range of 40–60, the infusion pump speed was adjusted according to a gradient of 0.2 mg/kg/h, with administration terminated 5 min before the end of surgery.

Data Collection

During the study period, we examined the patients' clinical records and collected the following data: demographic information (age, gender, body mass index [BMI], American Society of Anesthesiologists [ASA] classification (Aronson et al, 2003), principal diagnosis at admission, surgical techniques, duration of surgery and intraoperative blood loss); anesthesia indices (time to anesthesia onset, recovery time, length of stay in the post-anesthesia care unit [PACU]); and data on recovery quality (Riker sedation-agitation scale [SAS] (Riker et al, 1999) and confusion assessment method-Chinese revision [CAM-CR] derived from the Confusion Assessment Method) (Inouye et al, 1990). The SAS and CAM-CR scoring on 160 patients undergoing colorectal cancer surgery was performed by anesthesiologists. Adverse events were recorded within one week postoperatively. Hemodynamic indices such as mean arterial pressure (MAP) and heart rate (HR) were recorded in both groups at 3 min before anesthesia (T1), 30 min after anesthesia (T2), immediately after surgery (T3), and 5 min after surgery (T4). To measure the levels of inflammatory factors, 3 mL of peripheral venous blood was collected from patients on preoperative day 1, immediately after surgery, postoperative days 1, 3, and 5. The levels of inflammatory factors such as interleukin (IL)-6, IL-8, and tumor necrosis factor alpha (TNF-α) were measured using enzyme-linked immunosorbent assay (ELISA) (IL-6, ab178013; IL-8, ab214030; and TNF-α, ab285312, Abcam, Cambridge, UK).

Postoperative Follow-Up

The patients were followed up postoperatively in the outpatient clinic every 3 months for the first 2 years, and every 6 months for the next 3 years, and then annually thereafter.

Table 1. Comparison of baseline characteristics between the study and control groups.

	Study group (n = 85)	Control group (n = 75)	t/χ^2	p-value
Age (years)	58.01 ± 3.82	57.76 ± 3.87	0.411	0.682
BMI (kg/m^2)	22.49 ± 2.49	23.09 ± 3.00	1.382	0.169
Gender, n (%)			0.025	0.874
Male	43 (50.6)	37 (49.3)		
Female	42 (49.4)	38 (50.7)		
ASA class, n (%)			0.311	0.577
I	40 (47.1)	32 (42.7)		
II	45 (52.9)	43 (57.3)		
Principal diagnosis at admission, n (%)			0.072	0.789
Colon cancer	30 (35.3)	28 (37.3)		
Rectal cancer	55 (64.7)	47 (62.7)		
Surgical techniques, n (%)			0.017	0.991
Laparoscopy	19 (22.4)	17 (22.7)		
Robotic	30 (35.3)	27 (36.0)		
Laparotomy	36 (42.4)	31 (41.3)		
Duration of surgery (min)	188.12 ± 22.01	190.16 ± 18.08	0.636	0.526
Intraoperative blood loss (mL)	123.89 ± 29.09	119.33 ± 28.08	1.006	0.316

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index.

Statistical Analysis

The statistical analysis was performed using the SPSS software (version 23.0, SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk method was used to assess the data distribution of continuous variables. Continuous variable data were expressed as mean ± standard deviation and compared between groups using independent sample t-test, and within-group comparisons were performed using paired sample t-test. Categorical data are expressed as counts and percentages, and group comparisons were conducted using the chi-squared test. $p < 0.05$ was considered statistically significant.

Results

Comparison of Baseline Characteristics

There were no significant differences in gender, age, BMI and ASA classification between the study and control groups ($p > 0.05$). There was no statistically significant difference in the primary diagnosis at admission, surgical techniques, duration of surgery, and intraoperative blood loss between the two groups of patients ($p > 0.05$) (Table 1).

Comparison of Anesthesia Indices

In the study group, the time to anesthesia onset, recovery duration, and the length of stay in PACU were shorter compared to the control group, with the differences being statistically significant ($p < 0.05$), as shown in Table 2.

Table 2. Comparison of anesthesia indices between the study and control groups.

Groups	Time to anesthesia onset (min)	Recovery duration (min)	Length of stay in PACU (min)
Study group	1.60 ± 0.25	5.50 ± 1.50	30.50 ± 5.50
Control group	2.89 ± 0.50	10.10 ± 2.00	38.60 ± 6.40
t	21.002	16.573	8.610
p-value	<0.001	<0.001	<0.001

Abbreviations: PACU, post-anesthesia care unit.

Table 3. Comparison of recovery quality indicators between the study and control groups.

Groups	SAS	CAM-CR
Study group	4.10 ± 0.40	12.50 ± 1.20
Control group	5.80 ± 0.80	18.20 ± 0.95
t	17.298	33.006
p-value	<0.001	<0.001

Abbreviations: CAM-CR, confusion assessment method-Chinese revision; SAS, Riker sedation-agitation scale.

Evaluation of Recovery Quality Scores

The study group demonstrated significantly lower SAS and CAM-CR scores compared to the control group ($p < 0.05$), as shown in Table 3.

Comparison of Hemodynamic Indices at Different Time Points

At T1, the difference in MAP and HR between the two groups was not significant ($p > 0.05$). At T2, T3, and T4, the MAP and HR were lower than those at T1 in both groups ($p < 0.05$), but these indices were higher in the study group than in the control group ($p < 0.05$), as shown in Table 4.

Comparison of the Incidence of Adverse Reactions

For one week after surgery, the occurrence of adverse reactions in the study group was 10.59% (9/85), which was lower than 37.33% (28/75) observed in the control group ($p < 0.05$), as shown in Table 5.

Comparison of Inflammatory Factor Levels

On the day before surgery, no significant difference in the examined inflammatory factor levels was observed between the two groups ($p > 0.05$). At the same postoperative period, IL-6, IL-8 and TNF-α levels in the study group were lower than those in the control group ($p < 0.05$). The levels of IL-6, IL-8 and TNF-α after surgery in both groups were significantly higher than 1 day preoperative ($p < 0.05$), as shown in Table 6.

Table 4. Comparison of hemodynamic indices at different time points between the study and control groups.

	Time points	Study group	Control group	*t*	*p*-value
MAP (mmHg)	T1	85.60 ± 5.15	85.35 ± 2.20	0.390	0.697
	T2	80.50 ± 4.65 $^{\alpha}$	75.64 ± 6.25 $^{\alpha}$	5.621	<0.001
	T3	80.93 ± 2.54 $^{\alpha}$	75.89 ± 5.32 $^{\alpha}$	7.788	<0.001
	T4	83.15 ± 5.60 $^{\alpha}$	80.23 ± 4.50 $^{\alpha}$	3.604	<0.001
HR (beats/min)	T1	72.18 ± 5.53	72.50 ± 3.45	0.432	0.666
	T2	68.68 ± 5.54 $^{\alpha}$	65.06 ± 3.21 $^{\alpha}$	4.969	<0.001
	T3	68.15 ± 4.03 $^{\alpha}$	65.35 ± 2.09 $^{\alpha}$	5.408	<0.001
	T4	70.89 ± 5.55 $^{\alpha}$	66.56 ± 1.10 $^{\alpha}$	6.640	<0.001

Notes: $^{\alpha}$ $p < 0.05$ compared to T1. T1, 3 min before anesthesia; T2, 30 min after anesthesia; T3, immediately after surgery; T4, 5 min after surgery.
Abbreviations: HR, heart rate; MAP, mean arterial pressure.

Table 5. Comparison of the incidence of adverse reactions between the study and control groups.

Group	*n*	Nausea and vomiting	Hiccup	Agitation	Respiratory depression	Headache	Rate of occurrence
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Study group	85	2 (2.35)	1 (1.18)	2 (2.35)	3 (3.53)	1 (1.18)	9 (10.59)
Control group	75	6 (8.00)	5 (6.67)	7 (9.33)	7 (9.33)	3 (4.00)	28 (37.33)
χ^2							16.032
p-value							<0.001

Discussion

Colorectal cancer is a prevalent malignancy in clinical settings, with the majority of patients choosing surgical interventions as treatment. However, it is crucial to note that the chosen anesthesia method affects not only the anesthesia efficacy but also the patient's hemorheology and hemodynamic indices, which in turn affects the surgical effect and prognosis of patient's recovery. Therefore, the choice of anaesthesia method should be given much emphasis (Wu et al, 2018). Propofol is mainly used for induction and maintenance of anesthesia, but the use of this drug in high doses could predispose patients to respiratory depression and hemodynamic fluctuations (Liu et al, 2023; Wu et al, 2018). Comparatively, remimazolam—an ultra-short-acting sedative drug—is known for its immediate onset of action and rapid metabolism, and fast recovery from sedation is possible in its users (Sun and Sun, 2024).

The findings of this study indicated that in the remimazolam group, the time to anesthesia onset, recovery duration, and the length of stay in PACU were all significantly shorter compared to the propofol group. Remimazolam is a γ-aminobutyric acid receptor agonist with a rapid onset of action and a half-life of only 45 min, and its metabolite, zolenpropionic acid, is not pharmacologically active; these attributes

Table 6. Comparison of inflammatory factor levels between the study and control groups.

Groups	Time points	Study group	Control group	*t*	*p*-value
IL-6 (pg/mL)	1 day preoperative	18.32 ± 2.01	18.56 ± 2.16	0.728	0.468
	Immediately after surgery	22.32 ± 4.30 $^{\alpha}$	27.90 ± 5.32 $^{\alpha}$	7.331	<0.001
	1 day postoperative	55.27 ± 5.24 $^{\alpha}$	61.58 ± 6.40 $^{\alpha}$	6.853	<0.001
	3 days postoperative	58.30 ± 6.90 $^{\alpha}$	79.56 ± 7.45 $^{\alpha}$	18.735	<0.001
	5 days postoperative	32.87 ± 4.09 $^{\alpha}$	41.75 ± 7.54 $^{\alpha}$	9.405	<0.001
IL-8 (pg/mL)	1 day preoperative	17.86 ± 1.45	17.70 ± 1.05	0.790	0.431
	Immediately after surgery	29.22 ± 5.33 $^{\alpha}$	34.38 ± 4.05 $^{\alpha}$	6.823	<0.001
	1 day postoperative	61.27 ± 7.30 $^{\alpha}$	68.12 ± 6.99 $^{\alpha}$	6.042	<0.001
	3 days postoperative	64.52 ± 3.55 $^{\alpha}$	71.13 ± 6.34 $^{\alpha}$	8.258	<0.001
	5 days postoperative	31.40 ± 3.50 $^{\alpha}$	36.10 ± 4.32 $^{\alpha}$	7.596	<0.001
TNF-α (pg/mL)	1 day preoperative	14.28 ± 1.06	14.46 ± 0.88	1.160	0.248
	Immediately after surgery	32.73 ± 4.06 $^{\alpha}$	39.69 ± 6.58 $^{\alpha}$	8.152	<0.001
	1 day postoperative	56.18 ± 5.26 $^{\alpha}$	60.99 ± 6.36 $^{\alpha}$	5.234	<0.001
	3 days postoperative	57.20 ± 4.30 $^{\alpha}$	67.59 ± 6.30 $^{\alpha}$	12.302	<0.001
	5 days postoperative	37.56 ± 4.56 $^{\alpha}$	47.53 ± 6.99 $^{\alpha}$	10.803	<0.001

Notes: $^{\alpha}$ $p < 0.05$ compared to 1 day preoperative.
Abbreviations: IL-6, interleukin-6; IL-8, interleukin-8; TNF-α, tumor necrosis factor alpha.

offer justifiable explanations for the more rapid postoperative awakening for patients receiving remimazolam than for propofol users (Li et al, 2021). Interestingly, one meta-analysis showed that the depth of remimazolam-induced anesthesia was less compared with propofol, whereas the time to loss of consciousness was longer with remimazolam than with propofol. Although there were no differences in time to eye opening and time to extubation, remimazolam was associated with a lower risk of pain (Ko et al, 2023). In addition, SAS and CAM-CR scores were lower in the remimazolam group than in the propofol group, and the subjects of the remimazolam group recorded higher MAP and HR at T2, T3 and T4 compared to the propofol group. It has been reported that upon entry into the body system, propofol dilates the peripheral vasculature, directly lowering blood pressure levels, whereas remimazolam does not dilate blood vessels and therefore has a smaller effect on blood pressure levels than propofol (Zhang et al, 2024). Remimazolam exerts its sedative effect mainly by increasing the permeability of intracellular membranes, and its rapid metabolism and low impact on the circulatory system are conducive to the maintenance of hemodynamic stability, thus improving the recovery quality (Tian et al, 2024). Concordantly, Sun and Sun (2024) found that remimazolam effectively stabilizes hemodynamics and reduces pain levels.

In the current study, we found a lower incidence of postoperative adverse events in the remimazolam group compared with the propofol group, consistent with findings of a previous study by Zhang et al (2024). In addition, in elderly patients undergoing hip replacement, remimazolam users had significantly lower rate of adverse reactions compared to patients receiving propofol (Zhang et al, 2022). This can be caused by the fact that remimazolam is selective and short-acting, thus

allowing for a faster return to wakefulness at the end of the procedure and a reduction in the incidence of adverse anesthetic reactions. The clinical symptoms of colorectal cancer are associated with an inflammatory response, and surgery is an invasive procedure that promotes the release of inflammatory factors (Alexander et al, 2020). The IL-6, IL-8 and TNF-α are common pro-inflammatory factors that mediate inflammation and increase postoperative pain (Cocea and Stoica, 2024). However, the inflammatory response to general anesthesia induced by remimazolam and propofol after colorectal cancer surgery has not been reported. In this study, the inflammatory factor levels of the two groups increased significantly after surgery, but the levels of IL-6, IL-8 and TNF-α in the remimazolam group were lower than those in the propofol group, indicating that remimazolam could reduce the production of inflammatory factors and the levels of pro-inflammatory factors, as part of its effect in attenuation of the inflammatory response. Liu et al (2025) also confirmed that Remimazolam can reduce the occurrence of inflammation. Study has found that differences in postoperative inflammatory markers correlated with clinical outcomes of adverse events (González-Martínez et al, 2015).

There are several limitations to this study. Firstly, the fact that the study was conducted in only one hospital may affect the reliability of the conclusions. Secondly, this study used a retrospective design. Future studies should use larger sample sizes and prospective multicenter studies to improve the universality and reliability of the results. This is especially important to strengthen the value of remimazolam for clinical application and to provide a reference for clinical practice.

Conclusion

In conclusion, remimazolam outperforms propofol in the induction of general anesthesia for patients undergoing colorectal cancer surgery, evidenced by the improvement of recovery quality and hemodynamic levels, as well as reduction of adverse effect incidence and attenuation of inflammatory responses.

Key Points

- Remimazolam is more effective than propofol in improving the recovery quality of patients after general anesthesia induced for colorectal cancer surgery.
- Remimazolam is more effective in improving the hemodynamic level of patients.
- Compared with propofol, remimazolam reduces the incidence of adverse events in patients.
- Compared with propofol, remimazolam is more effective in alleviating inflammation after colorectal cancer surgery.

Availability of Data and Materials

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

Author Contributions

FW and HZhang designed the research study and wrote the first draft. FW and HZhuo performed the research. FW and HZhuo analyzed the data. 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

This study has been approved by the Ethics Review Committee of the First People's Hospital of Xiaoshan District (No. 2025-11). The present study was conducted in strict adherence to the Declaration of Helsinki. Informed consent was obtained by all patients included in this study.

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Conflict of Interest

The authors declare no conflict of interest.

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