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Comparing the effect of remimazolam and propofol anesthesia on extubation time, hospital stay and psychological wellbeing post pediatric tonsillectomy and adenoidectomy

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Abstract

Background Chronic tonsillitis and adenoid hypertrophy can significantly impact children's growth and development, making surgical intervention necessary. The choice of anesthesia is critical to ensuring both safety and efficacy during such procedures. Propofol and remimazolam are commonly used anesthetic agents, but their relative advantages in pediatric surgery have not been thoroughly explored. Therefore, this study examines the comparative effects of propofol and remimazolam anesthesia in pediatric patients undergoing tonsillectomy and adenoidectomy. We hypothesized that remimazolam would result in more stable intraoperative vital signs, faster postoperative recovery, and fewer adverse events than propofol.

Methods In this comparative study, 193 pediatric patients from the Maternal and Child Health Hospital of Hubei Province in Wuhan, China, were enrolled between October 2021 and October 2023. Of these, 83 received propofol anesthesia and 110 received remimazolam anesthesia. The study assessed hemodynamic parameters, including heart rate, blood pressure, and oxygen saturation, at several time points, along with various recovery outcomes such as surgical duration, time to spontaneous respiratory recovery, extubation, and postoperative hospital stay. Moreover, post-extubation coughing, CHEOPS pain score, Ramsay score, Sedation-Agitation Scale (SAS) and rate of adverse reactions were compared between the two groups of pediatric patients subsequent to surgery.

Results The differences in HR, SBP, DBP, and SpO_2 between groups and time points were statistically significant ($P < 0.01$). The vital signs of the remimazolam group were more stable than those of the propofol group at each time point. The surgical duration did not show a substantial variance between the two groups ($P > 0.05$), but the remimazolam group displayed shorter times for spontaneous respiratory recovery, eye-opening upon verbal

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stimulation, awakening, discontinuation of monitoring, postoperative hospital stay, tracheal extubation, and recovery of consciousness after extubation compared to the propofol group ($P < 0.01$). Furthermore, there were statistically significant differences in the CHEOPS pain score, Ramsay score, and SAS score between groups and time points ($P < 0.01$). The CHEOPS pain score, Ramsay score, and SAS score at time points T_2 and T_3 were lower in the remimazolam group compare with the propofol group, and these differences held statistical significance ($P < 0.05$). Moreover, the remimazolam group exhibited a lower probability of postoperative hypotension and bradycardia versus the propofol group, and the remimazolam group exhibited a reduced overall occurrence of adverse reactions, with differences containing statistical differences ($P < 0.05$).

Conclusion In conclusion, remimazolam offers superior stability, faster recovery, and fewer complications compared to propofol. These findings support the use of remimazolam as a safer and more efficient anesthetic agent for pediatric tonsillectomy and adenoidectomy.

Keywords Propofol, Remimazolam, Tonsil, Adenoid, Length of stay

Introduction

Chronic tonsillitis, a common pharyngeal and laryngeal disease, is primarily triggered by recurrent attacks of acute tonsillitis, viral proliferation and infection of the palatine tonsils, bacterial infections in the tonsillar crypts, or impaired drainage of the tonsillar crypts [1, 2]. If not treated promptly, chronic tonsillitis can lead to adenoid hypertrophy (AH), bringing about a variety of symptoms. For instance, if AH blocks the posterior nares, rhinitis and nasosinusitis will follow, causing nasal congestion and a runny nose. If AH blocks the pharyngeal opening of the auditory tube, secretory otitis media (SOM) will be triggered. Moreover, if the upper respiratory tract is blocked, it can generate sleep apnea, mouth breathing, and subsequent oxygen deprivation. In severe cases, it can lead to an adenoid face [3, 4], exerting a severe impact on the growth and development of children.

Currently, tonsillectomy and adenoidectomy is the main approach employed in clinical practice for pediatric AH and chronic tonsillitis [5]. Nevertheless, pediatric adenoidectomy is generally characterized by a short surgical duration and strong stimulation to the throat, which may lead to residual bleeding after the operation. Therefore, performing this procedure requires stable and moderately deep anesthesia management, as well as rapid postoperative recovery, to avoid complications such as laryngospasm and aspiration following extubation [6, 7]. This poses high demands on the induction and maintenance of anesthesia throughout the operation. Propofol is a rapidly effective, short-acting, and fast-recovering general anesthetic that redistributes quickly to peripheral tissues, exhibits rapid clearance, and ensures fast and smooth awakening. It is extensively utilized in clinical settings. Nonetheless, it has a certain degree of circulatory function suppression, reducing peripheral vascular resistance, lowering blood pressure, and potentially leading to hypotension or even respiratory pause when severe [8]. Remimazolam is a novel ultra-short-acting benzodiazepine drug that acts on gamma-aminobutyric acid type A receptors (GABA receptors). It has a rapid onset, a high clearance rate, and non-active metabolites [9]. Research findings have unveiled that exclusive utilization of remimazolam as the sole agent for both the initiation and sustenance of general anesthesia can yield desirable sedative outcomes while exerting negligible influence on respiratory function [10]. However, its application in pediatric tonsillectomy and adenoidectomy is less reported.

In this study, a retrospective analysis of clinical data from pediatric patients who received tonsillectomy and adenoidectomy was performed. The study investigated the application value and effects of propofol and remimazolam in anesthesia for pediatric tonsillectomy and adenoidectomy, with the goal of exploring the optimal anesthesia protocol for such surgeries. We hypothesized that, compared to propofol, remimazolam would provide greater intraoperative hemodynamic stability, faster emergence and recovery, and a lower incidence of postoperative adverse events in children undergoing these procedures. The study hopes to provide more valuable references for the surgical anesthesia of children with tonsillar and adenoid hypertrophy.

Materials and methods

Study design and setting

This comparative study, conducted from October 2021 to October 2023, took place at the Maternal and Child Health Hospital of Hubei Province, Wuhan, China.

Sample size and sampling

Children undergoing tonsillectomy and adenoidectomy were selected using convenience sampling and divided into two groups based on the type of anesthesia used (propofol or remimazolam). The allocation to either the propofol or remimazolam group was not randomized. Instead, anesthetic choice was determined by the attending anesthesiologist based on clinical judgment, drug

availability, and individual experience with the anesthetic agents. There was no standardized protocol dictating the assignment of patients to a specific anesthetic group. The inclusion criteria were as follows: patients aged 2–12 years, children with indications for tonsillectomy and adenoidectomy [11, 12], ASA grade I–II [13], and the availability of complete clinical information. Exclusion criteria included age < 2 years or >12 years, ASA classification ≥ III, abnormal liver or kidney function, abnormal electrocardiogram, a history of previous tonsillectomy or adenoidectomy, a history of bronchial asthma, a recent history of upper respiratory tract infection, sensitivity to propofol or remimazolam, and recent use of sedatives or analgesics.

A total of 193 patients were identified and included in the study, with 83 assigned to the propofol group and 110 to the remimazolam group.

Measurement

In this study, a comprehensive set of clinical outcomes was measured to assess the intraoperative stability, recovery profile, and adverse effects associated with the use of remimazolam and propofol in pediatric tonsillectomy and adenoidectomy. These measurements were systematically categorized and are described below in detail.

Intraoperative hemodynamic monitoring

To evaluate the effects of the two anesthetics on vital signs, four key hemodynamic parameters were monitored throughout the surgery: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and peripheral oxygen saturation (SpO_2). These measurements were recorded at four predefined time points: (T0) before the induction of anesthesia, (T1) immediately after tracheal intubation, (T2) 30 min after the start of the operation, and (T3) at the end of surgery. This design allowed for the assessment of anesthetic stability over time.

Surgical and recovery time parameters

Several time-based variables were recorded to assess anesthetic recovery profiles. The surgical duration was measured from the first surgical incision to the final suture. The time to spontaneous respiratory recovery was defined as the interval between discontinuation of anesthetic agents and the first spontaneous breath detected via ventilator monitoring. Eye-opening time referred to the number of minutes from cessation of anesthetic drugs to when the child opened their eyes in response to a verbal command. Awakening time was calculated as the time from anesthesia cessation to the first purposeful response from the child (such as hand movement or head nodding). The time to monitor removal in the PACU was defined as the duration between PACU admission and the point at which the child met clinical criteria for discharge from monitoring (including stable vital signs, airway reflex recovery, and spontaneous respiration). Finally, the length of hospital stay was measured in full calendar days from the date of surgery to the date of discharge.

Post-extubation observations in the PACU

To evaluate airway and consciousness recovery, several variables were observed immediately after extubation. The extubation time was defined as the interval from discontinuation of anesthetic agents to successful tracheal tube removal, based on the return of protective airway reflexes and stable respiratory effort.

The recovery of consciousness after extubation referred to the time from tube removal to the child's ability to respond appropriately to verbal stimuli.

Additionally, cough severity after extubation was assessed using a standardized four-point ordinal scale adapted from Baculard et al. [14]: 1 indicated no cough, 2 represented mild coughing (1–2 coughs), 3 represented moderate coughing (3–4 coughs), and 4 represented severe coughing (5 or more coughs). Trained PACU staff documented these observations in real-time. Incidence of respiratory events, including hypoxia (defined as SpO_2 dropping >5% below baseline or falling below 95% for over 10 s), breath-holding episodes (lasting ≥ 20 s), and presence of laryngospasm or bronchospasm, was also recorded. This tool was translated into simplified Chinese by two bilingual anesthesiologists, then back-translated to French by a third expert to ensure semantic equivalence. The final version was reviewed for cultural appropriateness and clarity. Although not yet formally validated in Chinese pediatric populations, it was selected for its clinical relevance and observable behavioral criteria. Prior to data collection, all clinical staff involved in outcome assessment were trained in its use to ensure scoring consistency.

Pain, sedation, and agitation assessments in the ward

Pain was assessed using the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) scale [15], which evaluates six observable behavioral indicators: crying, facial expression, verbal expression, movement of the torso and legs, and response to touch at the surgical site. Each item is scored on a scale ranging from 0 to 2 or 1 to 3, depending on the behavior, resulting in a total score ranging from 4 to 13. A score of 4–5 indicates no or minimal pain, while scores ≥ 6 reflect increasing levels of discomfort requiring intervention.

Sedation levels were evaluated using the Ramsay Sedation Scale [16], which categorizes patient responsiveness to stimuli on a six-point scale. A score of 1 indicates no response to verbal or physical stimulation, while a score

of 6 represents an anxious or agitated state. Scores of 2 to 4 were considered optimal for the postoperative recovery period, suggesting the child was sedated but easily arousable. Children scoring 1 were observed more closely for signs of excessive sedation or respiratory depression, while those scorings 5 or 6 were monitored for potential agitation or discomfort.

Agitation was assessed using the Sedation–Agitation Scale (SAS) [17], a five-point behavioral scale adapted for pediatric use. A score of 0 reflects a deeply sedated, unresponsive state, while a score of 1 indicates the child is awake, calm, and cooperative. Scores of 2 to 4 reflect increasing levels of agitation, with a score of 4 indicating severe restlessness requiring physical restraint or intervention. A SAS score of 1 was considered optimal. Children who exhibited a score of 3 or higher were managed according to institutional protocol, which included intravenous administration of 1 mg/kg propofol if necessary to control severe agitation.

Postoperative adverse events (first 10 h after surgery)

The occurrence of adverse reactions was monitored during the first 10 h following extubation. Specifically, the following events were recorded: nausea and vomiting, hypotension (defined as age-adjusted SBP below the 5th percentile), bradycardia (defined as HR below 60 bpm or age-adjusted lower limit), shivering, and somnolence (failure to achieve an SAS score ≤ 2 within the expected recovery window). These events were assessed by clinical nurses and verified by the attending anesthesiologist.

Data collection

This study was approved by the Ethics Committee of Maternal and Child Health Hospital of Hubei Province. All procedures were performed in accordance with the ethical standards of the Institutional and National Research Committee and the principles of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Preoperative preparation

All patients were instructed to abstain from food for at least 8 h before the procedure. Upon entering the operating room, heart rate (HR) and blood oxygen saturation were continuously monitored. Intravenous access was established, and oxygen was administered through a face mask.

Anesthesia induction

Propofol Group: Patients received an intravenous injection of propofol (Batch No: 16SF7959, Fresenius Kabi Austria GmbH, Beijing) at a dose of 2 mg/kg.

Remimazolam Group: Patients received an intravenous injection? of remimazolam (Batch No: 230731AS, Jiangsu Hengrui Medicine Co., Ltd.) at a rate of 0.1–0.3 mg/kg.

Once unconsciousness was achieved, fentanyl (2–3 μg/kg) and cisatracurium (0.3 mg/kg) were administered intravenously to facilitate tracheal intubation. Mechanical ventilation was initiated with the following parameters: tidal volume of 6 ml/kg, fraction of inspired oxygen set to 60%, and a positive end-expiratory pressure (PEEP) of 5 cmH_2O (1 $cmH_2O = 0.098$ kPa).

Anesthesia maintenance

Propofol Group: Continuous intravenous infusion of propofol at 4–12 $mg{\cdot}kg^{-1}{\cdot}h^{-1}$.

Remimazolam Group: Continuous intravenous infusion of remimazolam at 0.5–1.0 $mg{\cdot}kg^{-1}{\cdot}h^{-1}$.

Both groups received remifentanil via intravenous infusion at a rate of 0.05–0.20 $\mu g{\cdot}kg^{-1}{\cdot}min^{-1}$. The body temperature was monitored throughout the surgery and maintained within the normal range. Remifentanil infusion was stopped 10 min before the end of the procedure.

Emergence and extubation

At the conclusion of the surgery, all anesthetic agents were discontinued. Respiratory and oral secretions were cleared, and oxygen was provided via manual ventilation. Once patients regained airway reflexes, intravenous neostigmine (0.02 mg/kg) and atropine (0.01 mg/kg) were administered to reverse muscle relaxation. Patients were extubated upon meeting the following criteria: return of cough and swallowing reflexes, spontaneous eye-opening and response to simple commands and muscle strength assessed as greater than grade 2. Following extubation, oxygen was delivered through a face mask.

Post-anesthesia care

Patients were transferred to the post-anesthesia care unit (PACU) for 30–60 min of observation. During this time, HR, oxygen saturation, and respiratory function were continuously monitored. Patients were considered stabilized when the following conditions were met: oxygen partial pressure > 95% on room air, full recovery of swallowing and cough reflexes and stable and effective respiratory function. Once these criteria were satisfied, cardiac monitoring was discontinued. Additional assessments, including sedation levels and pain, were conducted during the recovery period.

Data analysis

IBMSPSS Statistics 20.0 software (SPSS Inc., Chicago, IL, USA) was harnessed for data processing and analysis in this research. The representation of measurement data followed the format of ($\bar{\chi} \pm s$), and T-tests were employed for group comparisons. The presentation of enumeration

Table 1 Comparison of general data between the two groups (*n*, %) ($\overline{x} \pm s$)

Group	Age (years old)	Male	Female	Body mass index (kg/m^2)	Anesthesia duration (min)	Time of observation after awakening(min)
Propofol ($n=83$)	3.57 ± 0.36	46 (55.42)	37 (44.58)	18.67 ± 2.41	57.43 ± 9.78	38.65 ± 6.76
Remimazolam($n=110$)	3.49 ± 0.37	58 (52.73)	52 (47.27)	19.12 ± 3.12	56.32 ± 9.65	39.45 ± 7.54
T/χ^2	1.504	0.138		1.091	0.787	0.763
P value	0.134	0.710		0.277	0.433	0.447

Table 2 Intraoperative vital sign changes in the two groups ($\overline{x} \pm s$)

Indicator	Group	T_0	T_1	T_2	T_3	$F_{inter-group}/P_{inter-group}$	F_{time}/P_{time}	$F_{interaction}/P_{interaction}$
HR (time/min)	Propofol ($n=83$)	80.45 ± 10.54	86.25 ± 10.21	90.27 ± 8.32	91.76 ± 9.28	69.620/<0.0001	24.800/<0.0001	5.539/0.009
	Remimazolam ($n=110$)	90.39 ± 9.59	92.69 ± 8.12	95.27 ± 9.32	93.76 ± 11.28			
SBP (mmHg)	Propofol ($n=83$)	104.36 ± 11.15	101.71 ± 11.35	96.41 ± 11.58	95.32 ± 11.46	75.130/<0.001	9.312/<0.001	4.813/0.003
	Remimazolam ($n=110$)	107.32 ± 10.87	107.11 ± 11.36	105.67 ± 11.24	106.21 ± 11.37			
DBP (mmHg)	Propofol ($n=83$)	56.65 ± 5.98	55.25 ± 6.18	52.32 ± 6.14	50.39 ± 5.93	110.100/<0.001	8.643/<0.001	7.432/<0.001
	Remimazolam ($n=110$)	58.23 ± 8.21	60.87 ± 8.15	59.31 ± 8.32	58.76 ± 8.34			
SpO_2 (%)	Propofol ($n=83$)	96.58 ± 1.73	97.12 ± 2.86	98.01 ± 1.56	97.11 ± 1.36	59.070/<0.0001	15.570/<0.0001	5.039/0.0018
	Remimazolam ($n=110$)	97.39 ± 2.23	98.69 ± 1.22	98.27 ± 1.32	98.36 ± 1.28			

Heart rate (*HR*). systolic blood pressure (*SBP*), diastolic blood pressure (*DBP*) blood oxygen saturation (SpO_2)

data was in the form of (*n*, %), and the comparison was carried out utilizing the χ^2 test. The analysis of relevant indicators at different time points between the two groups was performed using repeated measures analysis of variance. When $P<0.05$, statistical significance could be confirmed.

Results

General information of all patients

Table 1 presents the general information of the patients in both groups. The results indicate that there were no statistically significant differences between the two groups regarding age, gender, BMI, duration of anesthesia, and observation time after awakening ($p>0.05$).

Intraoperative vital sign changes in the two groups

The analysis unraveled that there were statistically significant variances ($P<0.001$) in HR, SBP, DBP, and SpO_2 between groups and time points. Additionally, the abovementioned parameters in the propofol group were lower than those in the remimazolam group, suggesting that the propofol group exhibited greater changes in vital signs and had poorer hemodynamic stability compared to the remimazolam group. Refer to Table 2 for details.

Comparison of surgical-related indicators between the two groups

The recorded surgical-related indicators in the two groups of pediatric patients unveiled no statistically significant difference in the duration of surgery ($P>0.05$). Nevertheless, the remimazolam group exhibited shorter times for the recovery of spontaneous breathing, eye-opening upon calling, awakening, monitoring removal, and postoperative hospital stay compared to the propofol group, with statistically significant differences ($P<0.05$). This demonstrated that the application of remimazolam anesthesia facilitated postoperative recovery and shortened hospitalization time in pediatric patients. Refer to Table 3 for more information.

Recording of tracheal extubation time, recovery of consciousness after extubation, and coughing in the two groups

These findings demonstrated that in contrast to the propofol group, the remimazolam group had shorter tracheal extubation time and faster recovery of consciousness after extubation. These differences were found to be statistically significant ($P<0.05$). In the propofol group, 11 patients experienced coughing after extubation, whereas in the remimazolam group, 7 patients underwent coughing. The incidence of coughing was notably higher in the propofol group than in the remimazolam group

Table 3 Comparison of surgical-related indicators between the two groups ($\overline{x} \pm s$)

Group	Surgical duration (min)	Time to recovery of spontaneous breathing (min)	Time of eye-opening upon calling (min)	Awakening time (min)	Time to monitoring removal (min)	Length of hospital stay (d)
Propofol ($n=83$)	69.45 ± 7.03	19.25 ± 2.13	45.21 ± 4.76	26.76 ± 3.18	44.76 ± 6.28	6.63 ± 1.36
Remimazolam ($n=110$)	71.22 ± 7.45	12.21 ± 1.46	23.54 ± 3.24	22.71 ± 3.21	41.43 ± 6.54	3.45 ± 1.31
T	1.674	27.220	37.594	8.713	3.562	16.424
P value	0.096	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 4 Recording of tracheal extubation time, recovery of consciousness after extubation, and coughing in the two groups ($\overline{x} \pm s$; *n*, %)

Group	Tracheal extubation time (min)	Recovery of consciousness after extubation (min)	Number of cases of coughing after extubation (*n*, %)			Breath-holding or insufficient oxygenation (*n*, %)	Laryngospasm or bronchospasm (*n*, %)
			Mild	Moderate	Severe		
Propofol ($n=83$)	53.41 ± 5.64	25.25 ± 2.63	6 (7.23)	3 (3.61)	2 (2.41)	2 (2.41)	0 (0.00)
Remimazolam ($n=110$)	32.27 ± 3.55	21.24 ± 2.41	5 (4.55)	2 (1.82)	0 (0.00)	2 (1.82)	0 (0.00)
T	31.844	8.652	11.380			0.082	-
P value	< 0.001	< 0.001	0.003			0.775	-

Table 5 Comparison of the CHEOPS pain score, Ramsay score, and SAS score between the two groups ($\overline{x} \pm s$)

Indicator	Propofol ($n=83$)	Remimazolam ($n=110$)	T	*P* value
CHEOPS score	8.34 ± 0.93	7.14 ± 0.78	9.737	< 0.001
Ramsay score	2.32 ± 0.26	1.81 ± 0.19	15.746	< 0.001
SAS score	2.61 ± 0.29	1.32 ± 0.16	39.398	< 0.001

Compared to the propofol group, $P<0.05$; CHEOPS pain score (cry, facial expression, speech, leg movement, torso movement, and touch on the wound)

($P<0.05$). Furthermore, no substantial difference was discovered in the occurrence of breath-holding or insufficient oxygenation between the two groups, and no cases of laryngospasm or bronchospasm occurred subsequent to extubation ($P>0.05$). All these findings confirmed that remimazolam anesthesia was beneficial in reducing postoperative extubation time, attenuating the incidence of post-extubation coughing, and promoting the recovery of consciousness in pediatric patients. See Table 4 for details.

Comparison of the CHEOPS pain score, Ramsay score, and SAS score

As evidenced by our analysis, there existed statistically significant variances in the CHEOPS pain score, Ramsay score, and SAS score between groups and time points ($P<0.001$). The CHEOPS pain scores (7.14 ± 0.78), Ramsay scores (1.81 ± 0.19), and SAS scores (1.32 ± 0.16) in the remimazolam group were lower than those in the propofol group [CHEOPS pain scores (8.34 ± 0.93), Ramsay scores (2.32 ± 0.26), SAS scores (2.61 ± 0.29)]. These outcomes reflected that the application of remimazolam anesthesia could alleviate pain, mitigate agitation, and facilitate the recovery of postoperative functional capacity in pediatric patients (Table 5).

Comparison of postoperative adverse event rates between the two groups

Upon comparing the incidence of adverse reactions such as nausea, vomiting, and shivering within 10 h after extubation between the two groups, it was observed that the remimazolam group exhibited a lower occurrence of hypotension and bradycardia compared to the propofol group. Furthermore, the overall incidence of adverse reactions in the remimazolam group was lower than that in the propofol group, and the variance contained statistical significance ($P<0.05$). These findings indicate that remimazolam was associated with fewer adverse reactions in this cohort of children undergoing tonsillectomy and adenoidectomy. However, as this was a non-randomized observational comparison, no definitive causal conclusions can be drawn. See Table 6 for details.

Discussion

Children with adenoid hypertrophy often have abnormal oral anatomy. Tonsillectomy and adenoidectomy are an intraoral procedure that, if not performed with caution, can easily cause respiratory aspiration or obstruction, and even death by suffocation. The anesthesia risk is high, and the surgical mortality rate is relatively high [18, 19]. Propofol, a widely used general anesthesia drug, boasts the advantages of rapid onset and quick recovery. It is

Table 6 Comparison of postoperative adverse event rates between the two groups (*n*, %)

Group	Nausea and vomiting	Hypotension	Bradycardia	Shivering	Somnolence	Overall incidence
Propofol (*n* = 83)	2 (2.41)	7 (8.43)	5 (6.02)	1 (1.20)	2 (2.41)	17 (20.48)
Remimazolam (*n* = 110)	3 (2.73)	2 (1.82)	1 (0.91)	1 (0.91)	2 (1.82)	9 (8.18)
χ^2	0.019	4.657	4.109	0.040	0.082	6.140
P value	0.891	0.031	0.043	0.841	0.775	0.013

extensively applied in pediatric tonsillectomy and adenoidectomy. Nevertheless, propofol, like other phenolic drugs, reportedly can trigger strong stimulation and pain in the skin, mucosa, and endangium. Although this pain is not a severe complication, it can be a significant source of excessive stress in the course of surgery in children and a limiting factor for ideal anesthesia [20]. Remimazolam, as a clinical anesthesia drug that has gained popularity in recent years, has also been gradually applied in pediatric surgery anesthesia. Studies have demonstrated that remimazolam rapidly binds to and dissociates from GABA receptors and is quickly hydrolyzed by tissue esterase in the body into inactive remifentanil acid, with an average duration of 0.57 h. It does not undergo hepatic or renal metabolism and has no cumulative effect during continuous infusion sedation, with the characteristics of rapid onset and metabolism [21]. In this research, these two types of general anesthesia drugs were taken for induction and maintenance during pediatric tonsillectomy and adenoidectomy. Different indicators of children anesthetized with various drugs were compared, aiming to select the appropriate anesthesia drug for children undergoing tonsillectomy and adenoidectomy, boost postoperative recovery, and improve quality of life.

Here, a total of 193 clinical data of pediatric patients who underwent propofol or remimazolam anesthesia were retrospectively analyzed. Hemodynamic indices such as HR, SBP, DBP, and SpO_2, were recorded prior to anesthesia induction, immediately after tracheal intubation, 30 min after the start of surgery, and at the end of surgery. However, the hemodynamics of patients anesthetized with remimazolam were more stable than those in the propofol group. This finding is consistent with the study conducted by Doi et al. [22], which has demonstrated that remimazolam is more effective than propofol in improving target-oriented hemodynamic management strategies. This may be because remimazolam, along with opioid drugs, maintains hemodynamic stability by suppressing sympathetic activities, whereas propofol exhibits cardiovascular inhibitory effects and causes peripheral vasodilation, reducing peripheral resistance and triggering a notable drop in blood pressure and HR [23–25]. Moreover, the SpO_2 of patients anesthetized with remimazolam was also superior to that of the propofol group. This may be due to the direct or indirect impact of propofol on the carotid body chemoreceptors, mitigating the body's sensitivity to hypercapnia and hypoxemia. In addition, a decrease in tissue blood perfusion can bring about relative tissue hypoxia [26, 27]. Thus, compared to propofol anesthesia, the vital signs of patients undergoing remimazolam anesthesia were more stable, which is aligned with the study conducted by Tang et al. [28].

Furthermore, our work discovered no statistically significant difference in the duration of surgery between the two groups of patients. However, the remimazolam group had remarkably shorter times for the recovery of spontaneous breathing, time to eye-opening upon calling, awakening time, discontinuation of monitoring, and postoperative hospital stay compared to the propofol group, with differences being statistically significant. The analysis suggests that this variance may be attributed to the metabolism of remimazolam is similar to that of remifentanil, is metabolized by esterase distributed throughout the body, and is independent of cellular P450 enzyme metabolism. In contrast to similar anesthetic drugs, remimazolam shows a faster onset of action, faster metabolism, and non-active metabolites. It also boasts a higher clearance rate and weaker drug interactions. The relatively shorter half-life of remimazolam compared to propofol may be a contributing factor [29, 30].

This research also displayed that by contrast with the propofol group, the remimazolam group had shorter extubation time and faster consciousness recovery after extubation, as well as a lower likelihood of coughing after extubation. Apart from factors such as perioperative cycle fluctuations, duration of surgery, pain stimuli, hypothermia, and catheter stimulation, relevant studies have unraveled that the primary mechanism for propofol-induced loss of consciousness is the suppression of higher cognitive cortical functions resulting from the drug [31, 32]. Additionally, Casali AG et al. conducted connectivity analyses between specific resting-state networks in the brain, such as the executive control network, default network, sensorimotor network, and the thalamus. Their findings have confirmed a linear correlation between the alterations in consciousness levels induced by propofol infusion and the decreased connectivity strength within the frontoparietal network and between the frontoparietal network and the thalamus. It has been observed that propofol administration during anesthesia in pediatric patients partially dampens cortical functions, hence contributing to delayed recovery of consciousness [33]. This discovery is consistent with the results of our research. It is also important to note that while

remimazolam appears to be associated with a favorable safety profile in the immediate postoperative period, it belongs to the benzodiazepine class, which has raised some concerns in pediatric populations. Current literature highlights potential long-term neurodevelopmental risks associated with repeated or prolonged exposure to general anesthetics in children under 3 years of age [34–36]. Although all participants in this study underwent a single, short-duration procedure, and the majority were above this age threshold, clinicians should continue to exercise caution and remain informed by evolving guidelines on pediatric anesthetic use.

Furthermore, our study findings also suggested that the CHEOPS pain scores, Ramsay scores, and SAS scores of patients in the remimazolam group were lower than those in the propofol group at 30 min after the initiation of surgery and at the conclusion of surgery. The primary reason is that propofol anesthesia exhibits a stronger stimulating effect on vascular endothelium than remimazolam, culminating in more pronounced pain sensations in patients. Additionally, propofol can directly act on transient receptor potential (TRP) channel proteins in the peripheral termination of the nerve, causing vasodilation and increased permeability. This leads to sensitization of spinal dorsal horn nerves and peripheral nerves, resulting in stronger pain perception by the body. Moreover, our study also revealed that during the recovery period, patients receiving propofol anesthesia were more likely to experience agitation compared to those receiving remimazolam anesthesia. This may be attributed to the inhibition of their higher cortical networks, and another contributing factor may be that the application of propofol anesthesia easily causes the desensitization blocking of inhibitory neuroreceptors and glycine receptors, hence augmenting the excitability of amino acid receptors [37, 38]. This finding bears consistency with the study by Xu GS et al. [39]. Additionally, our work confirmed that the incidence of bradycardia was lower in the remimazolam group than in the propofol group. Barring the myocardial inhibitory function of propofol, Natarajan et al. have also reported that remimazolam can bring about a slight increase in HR. Stimulation from traction during the surgical procedure can excite the vagus nerve and give rise to reflexive bradycardia [40, 41]. This substantiated that remimazolam anesthesia in pediatric tonsillectomy and adenoidectomy can better ameliorate pain sensation, attenuate postoperative agitation, and accelerate postoperative recovery compared to propofol.

The study has several notable limitations. First, being conducted at a single center, the findings may not be representative of other regions or healthcare settings. Additionally, the unequal group sizes, with 110 patients in the remimazolam group and 83 in the propofol group, could skew results and reduce statistical power. The short follow-up period, focusing only on immediate postoperative outcomes, fails to capture long-term recovery or delayed adverse effects. The study also lacks an economic analysis, omitting crucial factors like cost-effectiveness and availability. Lastly, the limited patient population—children undergoing tonsillectomy and adenoidectomy—restricts the findings to this specific group, making them less applicable to other patient types or surgical procedures. These limitations underscore the need for future studies to include multicenter designs, longer follow-up periods, balanced group sizes, economic evaluations, and broader patient populations to improve the robustness and applicability of the results.

Conclusion

In conclusion, both propofol and remimazolam have essential value in anesthesia for pediatric tonsil and adenoid surgeries. By contrast with propofol anesthesia, remimazolam anesthesia provides more stable hemodynamics in pediatric patients. It results in shorter postoperative awakening time, hospital stay, and extubation time, as well as better postoperative recovery. Therefore, it is worth considering remimazolam anesthesia in clinical anesthesia for pediatric tonsillectomy surgeries. Nevertheless, this research also has certain limitations, such as limitations in the enrollment period and study subjects, which prevented a more in-depth exploration of the influence of propofol and remimazolam anesthesia on pediatric tonsillectomy and adenoidectomy. Further studies will be conducted to address these limitations.

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Clinical trial number

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Authors' contributions

M.W., and X.Y. were major contributors to conceptualization and writing the manuscript. M.W., X.Y., R.Y., and X.G collected the patient data and followed up the patients. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Ethics Committee of Maternal and Child Health Hospital of Hubei Province (Ethic code No.2024IEC020). Wuhan, China approved the study. All participants were provided with a written informed consent form, clearly stating that their participation in the study was voluntary and that they had the right to withdraw at any time without facing any consequences. The participants were provided with detailed explanations about the confidentiality of their information. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
None.

Competing interests
The authors declare no competing interests.

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