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CLINICAL TRIAL REPORT

Comparative Evaluation of Remimazolam Besylate versus Propofol for Pediatric MRI Sedation: Safety, Recovery, and Adverse Event Profiles

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Objective: To evaluate the safety and efficacy of remimazolam besylate compared with propofol for pediatric MRI sedation.

Methods: Seventy-nine children undergoing MRI were randomly assigned to the remimazolam (R, n=39) or propofol (P, n=40) group. The primary observation indicator was the sedation success rate. Secondary indicators included the frequency of supplemental dosing, induction time, recovery time, and the incidence of adverse events (hypoxia, severe hypoxia, injection pain, hypotension, and bradycardia). Logistic regression and Spearman correlation were used to identify risk factors for adverse events.

Results: Sedation success rates were similar between groups (R: 92.3%, P: 95.0%; P=0.977). The R group showed longer induction (51.3 ± 25.9 s vs 38.5 ± 17.5 s, P=0.012) but faster recovery (12.1 ± 3.8 min vs 15.9 ± 4.6 min, P<0.001) and required fewer supplemental doses (≥2 doses: 23.1% vs 57.5%, P=0.002). Adverse events were less frequent with remimazolam. Logistic regression analysis revealed that recovery time, choice of sedative, and frequency of drug supplementation were significant risk factors for adverse events during pediatric MRI sedation. Prolonged recovery time (OR=1.454, 95% CI: 1.077–1.962, P=0.015) increased the risk of adverse events, whereas the use of remimazolam besylate significantly reduced this risk compared to propofol (OR=0.265, 95% CI: 0.145–0.486, P < 0.001). Patients needing ≥2 supplemental doses had higher risk (OR=2.188, 95% CI: 1.155–4.145, P=0.016). After adjustment, recovery time (adjusted OR=1.384, 95% CI: 1.064–1.800, P=0.015), ≥2 supplementations (adjusted OR=1.828, 95% CI: 1.267–2.637, P=0.001), and sedative type (adjusted OR=0.435, 95% CI: 0.214–0.883, P=0.021) remained independent predictors. Correlation analysis confirmed significant associations between recovery time, sedative choice, supplementation frequency, and adverse event occurrence (all P<0.05).

Conclusion: Remimazolam besylate and propofol are both safe and effective for pediatric MRI sedation, but remimazolam besylate is superior due to faster recovery and fewer adverse events.

Clinical Trial Number: This study was prospectively registered with the Chinese Clinical Trial Registry (ChiCTR), registration number: ChiCTR2500097093.

Keywords: remimazolam besylate, propofol, pediatric sedation, magnetic resonance imaging, adverse event

Introduction

With the advancement and diversification of magnetic resonance imaging (MRI) technology, its clinical applications in pediatrics have become increasingly widespread. However, the loud noise during MRI examinations and the need for complete immobility of the patient during the procedure often require infants and preschool children to undergo the examination under moderate to deep sedation or anesthesia.[1]

An ideal sedative for MRI should have rapid onset, minimal impact on respiratory and hemodynamic stability, fast recovery, and few side effects.[2] Considering the underdeveloped organ systems in children, careful drug selection is essential. Additionally, the pharmacokinetics of the sedative or anesthetic agents, including their metabolic pathways, are important considerations when planning these procedures, as they influence the choice of agents and dosage for optimal safety and efficacy.[2,3]

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Currently, propofol is the most commonly used sedative for pediatric patients. However, its use is associated with significant drawbacks, such as respiratory depression, apnea, hypotension, and injection pain.[3] Given these limitations, alternative sedatives with a better safety profile are needed. One such promising candidate is remimazolam besylate, an ultra-short-acting benzodiazepine with distinct pharmacokinetic properties.[4] Remimazolam besylate acts similarly to midazolam and offers several advantages, including rapid onset, short recovery time, minimal respiratory and circulatory suppression, and inactive metabolites.[4]

Despite its promising profile, there is limited research on its application in pediatric patients, and clinical data remain sparse. This study aims to evaluate whether remimazolam besylate is superior to propofol in terms of safety and effectiveness for sedation in pediatric MRI examinations. The hypothesis is that remimazolam offers distinct advantages over propofol, such as improved safety profiles or better sedation outcomes, while maintaining patient safety. The findings are expected to provide valuable evidence to guide clinical practice.

Materials and Methods

General Information

This prospective, randomized, controlled clinical study was approved by the Ethics Committee of Lianyungang Maternal and Child Health Hospital (Approval No. XM2022031), and adhered to the ethical principles outlined in the Declaration of Helsinki. Informed consent was obtained from the parents or legal guardians of all participants prior to study enrollment. A total of 80 children, aged 1 to 6 years, scheduled for painless cranial magnetic resonance imaging (MRI) at Lianyungang Maternal and Child Health Hospital between February 13, 2025 and March 29, 2025, were enrolled. The participants were classified according to the American Society of Anesthesiologists (ASA) as Grade I or II. Exclusion criteria included: allergies to benzodiazepines or propofol; significant dysfunction of vital organs such as the heart, liver, or kidneys; difficult airway conditions; or participation in other clinical studies within the past three months. Subjects were randomly assigned to either the remimazolam group (Group R) or the propofol group (Group P) using a random number table A single-blind design was used because the two drugs appeared different. The researchers who administered the anesthetics were not blinded; however, both the statistician and the outcome assessors were blinded to group assignment during data collection and analysis. Endoscopy physicians, nurses, patients, and investigators were blinded to group assignments. This study was prospectively registered with the Chinese Clinical Trial Registry (ChiCTR), registration number: ChiCTR2500097093.

Sedation Protocol

All children underwent pre-examination evaluations and were required to fast for 4–8 hours (4 hours for breast milk, 6 hours for formula milk, and 8 hours for solid food) and abstain from drinking fluids for 2 hours before the procedure. Intravenous access was established before sedation. Parents carried the children to the MRI examination table, where oxygen was administered via a nasal cannula connected to an oxygen bag. Vital signs were continuously monitored using a specially designed MRI-compatible monitor.

Propofol (10 mg/mL; batch number H19990282, Jiangsu Hengrui Pharmaceuticals Co., Ltd.) and remimazolam besylate (batch number 201031AK; Jiangsu Hengrui Pharmaceuticals Co., Ltd.) were prepared for administration. Remimazolam was diluted with saline to a concentration of 1 mg/mL. Due to differences in the appearance and dosage of the drugs, anesthesiologists were aware of the group assignments.

Anesthetic induction: In Group P, 2% lidocaine (1 mg/kg) was administered intravenously, followed by propofol (3 mg/kg) after a 30-second interval. In Group R, remimazolam besylate (0.4 mg/kg) was administered intravenously. The depth of sedation was assessed using the Modified Observer's Assessment of Alertness/Sedation Scale (MOAA/S).[5] The MOAA/S score was used to assess the depth of sedation, with a score of 5 indicating the child was fully awake and responded quickly to normal-tone calling; a score of 4 indicated the child was slow to respond but could clearly recognize normal-tone calling; a score of 3 indicated the child responded only to loud or repeated calling; a score of 2 indicated the child responded to gentle nudging or shaking; a score of 1 indicated the child had no response to nudging or shaking but responded to painful stimuli; and a score of 0 indicated no response to painful stimuli. Once a sedation

score of 2 or lower on the MOAA/S scale was achieved (ie, moderate to deep sedation, but not general anesthesia with MOAA/S 0), parents exited the examination room, and the child's position was adjusted by the physician, who also fitted noise-canceling headphones before the MRI examination commenced.

In our study, the redosing of sedatives was adjusted based on the patient's weight. Specifically, the redosing regimen was as follows: Group P (Propofol): Additional doses of 1.5 mg/kg were administered; Group R (Remimazolam): Additional doses of 0.2 mg/kg were administered. Redosing was considered when the MOAA/S score rose above 2, or when the child exhibited purposeful movement, crying, or signs of arousal that interfered with the MRI procedure. The depth of sedation was continuously monitored using the MOAA/S scale, which was assessed every 2–3 minutes by the attending anesthesiologist, in combination with continuous physiological monitoring (SpO_2, HR, and blood pressure). The total number of additional doses was limited to three during the examination, and if sedation failure occurred (defined as requiring more than three additional doses), rescue sedation with propofol (2 mg/kg) was provided.

During sedation, the child's oxygen saturation (SpO_2) was closely monitored. If SpO_2 dropped to <95%, oxygen flow was increased. If SpO_2 fell below 90%, the head position was adjusted, a face mask with positive pressure ventilation was applied, and the MRI was paused if necessary. Bradycardia or hypotension was managed with fluid boluses and atropine as needed. Following the examination, the children were transferred to a recovery room for continued electrocardiographic monitoring.

Observational Outcomes

The success rate of sedation was defined as the primary endpoint. The following outcomes were observed and recorded. Sedation success rate, which was defined as the percentage of children in each group who successfully completed the MRI examination on the first attempt without the need for repeat imaging due to movement or hypoxia and with no more than three additional doses of medication. The number of additional medication doses administered during the procedure. Induction time, which was the duration from the start of drug administration until the MOAA/S score reached ≤2. Examination time, defined as the duration from the start of the MRI examination to its completion. Recovery time, defined as the interval from the last dose of medication until the child was able to open their eyes and respond to simple questions. For clarity, this study uses the term recovery time consistently, and it corresponds to what some literature refers to as awakening time. Hypoxia was defined as a blood oxygen saturation (SpO_2) < 95% during sedation, which was continuously monitored using the Contec CMS50D pulse oximeter, applied to the child's fingertip. The Contec CMS50D provides real-time SpO_2 and pulse rate readings, with audible alerts for critical oxygen levels. Severe hypoxia was identified when SpO_2 dropped below 90% during sedation. Injection pain was indicated by crying, avoidance, or verbal complaints during intravenous injection. Hypotension was defined as a decrease in systolic blood pressure (SBP) by more than 20% below 90 mmHg during sedation. Bradycardia was defined as a decrease in heart rate (HR) by more than 20% below 80 beats per minute in pediatric patients during sedation.

Statistical Analysis

Data analysis was performed using SPSS 20.0 statistical software. Based on the preliminary results, the sedation success rate was 93% for both the P and R groups. With a significance level of $\alpha = 0.05$ and a power of $1 - \beta = 0.8$, the required sample size for each group was calculated to be 36 patients. Considering a 10% dropout rate, a total of 40 patients per group were included in this study.

Normality of continuous variables was assessed using the Shapiro–Wilk test. Normally distributed data are presented as mean ± standard deviation and were compared using independent-sample *t*-tests; non-normally distributed data were analyzed using appropriate non-parametric tests. Categorical variables are expressed as n (%) and were compared using the χ^2 test or Fisher's exact test, as appropriate. Ordinal variables were analyzed with the rank-sum test. Prior to logistic regression analysis, multicollinearity among covariates was assessed using the variance inflation factor (VIF).

Logistic regression was used to identify factors associated with sedation success and to evaluate risk factors for sedation-related adverse events. For the latter, variables with $P < 0.05$ in univariate analyses were included in the multivariate model, including induction time, type of sedative (remimazolam vs propofol), recovery time, and the number

of additional doses (≥2 vs <2). This approach allowed us to model the relationship between multiple covariates and binary outcomes, thereby clarifying the independent contribution of each factor.

Furthermore, Spearman rank correlation analysis was conducted to assess the relationship between ordinal variables. This method was chosen to explore any potential monotonic associations between variables in cases where the data did not meet the assumptions required for parametric tests. The use of the Spearman rank test adds value by providing insights into non-linear relationships, complementing the parametric analyses and enriching the overall interpretation of the results. A P value of <0.05 was considered statistically significant.

Results

Comparison of General Characteristics

A total of 80 patients were recruited for this study, with one patient withdrawing due to drug infiltration into the subcutaneous tissue. Ultimately, 39 patients from the R group and 40 patients from the P group were included in the statistical analysis (Figure 1). No statistically significant differences were observed between the two groups in terms of sex ratio, age, or weight ($P > 0.05$, Table 1).

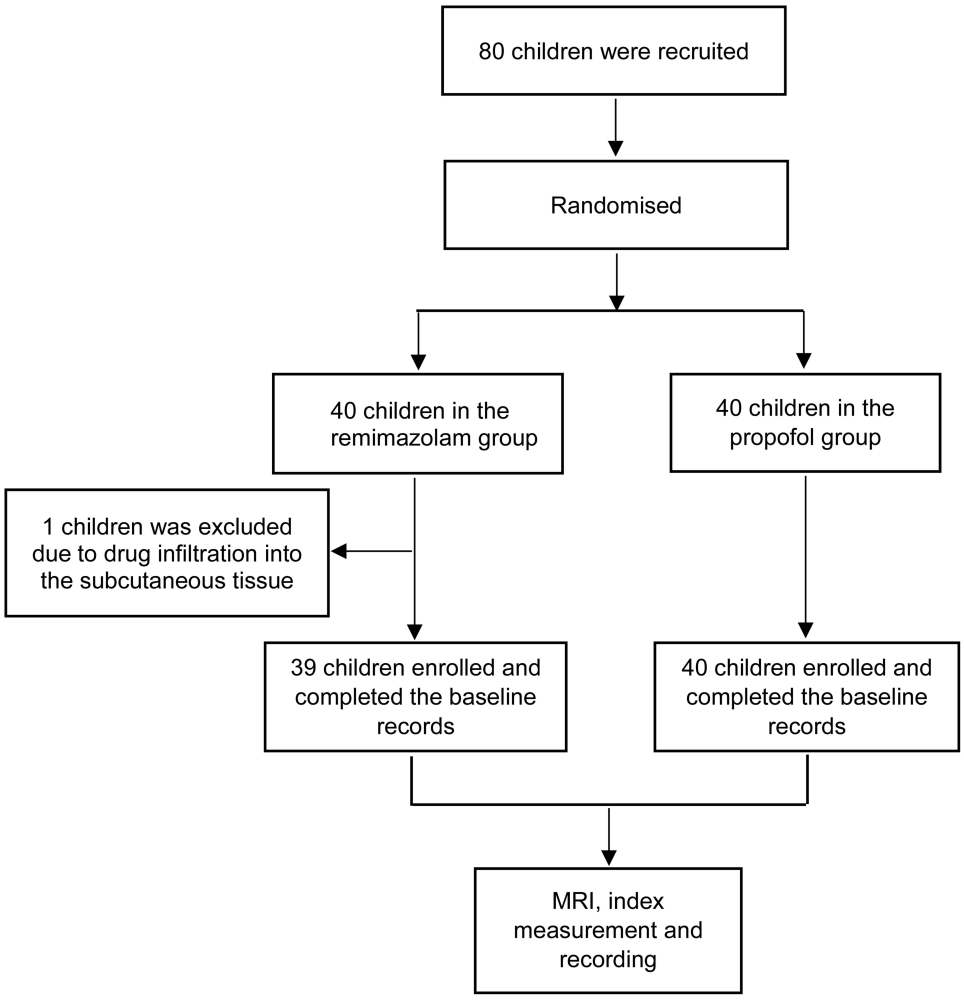

Figure 1 Flowchart of participants.

Table 1 Comparison of Sex Ratio, Age, Weight, and ASA Classification Between the Two Groups

Group	R Group (n=39)	P Group (n=40)	t/χ^2	*P*
Sex [n (%), male/female]	24 (61.5%)/15 (38.5%)	25 (62.5%)/15 (37.5%)	0.008	0.930
Age (years, mean±SD)	3.2 ± 1.5	2.9 ± 1.7	0.831	0.409
Weight (kg, mean±SD)	16.3 ± 4.6	16.9 ± 5.9	−0.503	0.616
ASA classification [n (%), I/II]	33 (84.6%)/6 (15.4%)	31 (77.5%)/9 (22.5%)	0.650	0.420

Abbreviations: R group, Remimazolam besylate group; P group, Propofol group; ASA, American Society of Anesthesiologists.

Comparison of Sedation Success Rate, Additional Drug Administration, Induction Time, Procedure Time, and Recovery Time

In the R group, two patients required more than three additional drug administrations, and one patient exhibited excessive movement necessitating a repeat examination. In the P group, two patients experienced severe hypoxia, requiring a repeat examination. The sedation success rate was comparable between the R and P groups (92.3% vs 95.0%, $\chi^2 = 0.001$, $P = 0.977$), with no statistically significant difference. Compared to the P group, the R group showed a significantly longer sedation induction time (51.3 ± 25.9 s vs 38.5 ± 17.5 s, t = 2.580, $P = 0.012$) but a significantly shorter recovery time (12.1 ± 3.8 min vs 15.9 ± 4.6 min, t = −3.998, $P < 0.001$). Procedure times did not differ significantly between the two groups (12.8 ± 1.8 min vs 13.3 ± 2.0 min, t = −1.167, $P = 0.247$). Additionally, the number of additional drug administrations was significantly lower in the R group than in the P group ($\chi^2 = 9.710$, $P = 0.002$). These results are summarized in Table 2.

Comparison of Adverse Events Between the Two Groups of Pediatric Patients

The incidence of severe hypoxia ($\chi^2 = 0.487$, $P = 0.485$), hypotension ($\chi^2 = 0.573$, $P = 0.449$), and bradycardia ($\chi^2 = 0.740$, $P = 0.390$) did not significantly differ between the two groups. However, the incidence of hypoxia ($\chi^2 = 5.313$, $P = 0.021$) and injection pain ($\chi^2 = 6.053$, $P = 0.014$) was significantly lower in the R group compared to the P group (Table 3).

Table 2 Comparison of Sedation Success Rate, Induction Time, Procedure Time, and Recovery Time Between the Two Groups

Group	R Group (n = 39)	P Group (n = 40)	t/χ^2	*P*
Sedation success rate [n (%)]	36 (92.3)	38 (95.0)	0.001	0.977
Induction time (s, mea±SD)	51.3 ± 25.9	38.5 ± 17.5	2.580	0.012
Procedure time (min, mean±SD)	12.8 ± 1.8	13.3 ± 2.0	−1.167	0.247
Recovery time (min, mean±SD)	12.1 ± 3.8	15.9 ± 4.6	−3.998	<0.001
Additional drug doses (≥2 times) [n (%)]	9 (23.1)	23 (57.5)	9.710	0.002

Abbreviations: R group, remimazolam besylate group; P group, propofol group.

Table 3 Comparison of Adverse Events Between the Two Groups

Group	R Group (n = 39)	P Group (n = 40)	χ^2	*P*
Hypoxia [cases (%)]	3 (7.7)	11 (27.5)	5.313	0.021
Severe hypoxia [cases (%)]	0 (0.0)	2 (5.0)	0.487	0.485
Hypotension [cases (%)]	2 (5.1)	5 (12.5)	0.573	0.449
Bradycardia [cases (%)]	5 (12.8)	8 (20.0)	0.74	0.39
Injection pain [cases (%)]	2 (5.1)	10 (25.0)	6.053	0.014

Abbreviations: R group, Remimazolam besylate group; P group, Propofol group.

Logistic Regression Analysis of Risk Factors for Sedation-Related Adverse Events in Pediatric MRI

Before performing the logistic regression analysis, we conducted a collinearity diagnostic on all variables included in the model, using the VIF as the evaluation criterion. The results showed that the VIF values for all variables were within an ideal range (the VIF for age was 3.2, for sex was 1.5, for weight was 4.7, for ASA classification was 2.9, for examination duration was 3.4, for induction time was 2.1, for sedative agent was 1.8, for recovery time was 3.0, and for additional drug dose was 4.3), all of which were well below the threshold of 10 that could indicate collinearity issues. This suggests that there was no significant collinearity between the variables in this study.

Logistic regression analysis revealed that recovery time, choice of sedative agent, and the frequency of additional drug administration are significant risk factors for sedation-related adverse events during pediatric MRI (Table 4). Prolonged recovery time was associated with a higher risk of adverse events (OR = 1.454, 95% CI: 1.077–1.962, P = 0.015). Compared to propofol, the use of remimazolam besylate significantly reduced the risk of adverse events (OR = 0.265, 95% CI: 0.145–0.486, P < 0.001). Patients requiring two or more additional doses of sedatives had a significantly higher risk than those requiring fewer than two doses (OR = 2.188, 95% CI: 1.155–4.145, P = 0.016). After adjusting for variables significant in univariate analysis, recovery time (adjusted OR = 1.384, 95% CI: 1.064–1.800, P = 0.015) and the frequency of additional drug administration (adjusted OR = 1.828, 95% CI: 1.267–2.637, P = 0.001) remained significantly associated with adverse events. Although the effect of the sedative agent choice was slightly attenuated, it remained statistically significant (adjusted OR = 0.435, 95% CI: 0.214–0.883, P = 0.021). These findings indicate that recovery time, sedative selection, and additional drug administration frequency are critical factors influencing the occurrence of sedation-related adverse events, warranting close attention in clinical practice.

Moreover, Spearman correlation analysis confirmed significant associations between sedative agent ($R_{Spearman}$=0.416, P<0.001, Figure 2A), recovery time ($R_{Spearman}$=0.845, P<0.001, Figure 2B), and additional drug administration frequency ($R_{Spearman}$=0.748, P<0.001, Figure 2C) with the occurrence of adverse events.

Discussion

This study demonstrates that remimazolam besylate provides significant advantages over propofol for pediatric MRI sedation. Although both drugs achieved high sedation success rates, remimazolam was associated with a markedly shorter recovery time, a lower incidence of adverse events such as hypoxia and injection pain, and reduced need for supplemental dosing. These findings highlight the clinical value of remimazolam as a safer and more efficient sedative option in this setting.

The use of sedation in pediatric outpatient clinics is becoming increasingly common, making the selection of sedative agents crucial.[6] An ideal pediatric sedative should possess the following characteristics: rapid onset, short duration of action, strong dose-dependent effects, quick recovery, maintenance of airway patency, spontaneous respiration, hemodynamic stability, absence of injection pain, and the availability of an antagonist.[7] Traditional agents such as midazolam and chloral hydrate are gradually being replaced by newer drugs like propofol and dexmedetomidine.[8] Two existing meta-analyses have compared the use of propofol and dexmedetomidine for pediatric MRI sedation, concluding that dexmedetomidine is associated with prolonged recovery. In contrast, propofol is more commonly recommended due to its superior sedative effects and lower incidence of delirium.[9,10] Therefore, this study selected propofol as the control group.

Remimazolam besylate is a novel general anesthetic belonging to the ultra-short-acting benzodiazepines. It is metabolized by tissue esterases into inactive compounds, characterized by a small volume of distribution at steady state and a short elimination half-life. Its advantages include rapid onset and clearance, minimal injection pain, anterograde amnesia, mild respiratory and circulatory depression, low dependence on hepatic and renal function, and the availability of a specific antagonist. These properties make it ideal for sedation and anesthesia in outpatient and surgical settings.[11] Previous studies in adults have demonstrated that remimazolam is safe and effective as a sedative for outpatient minor surgeries, with sedation efficacy comparable to propofol.[12] In this study, both the remimazolam group (R group) and the propofol group (P group) achieved high sedation success rates, with no significant difference between them. Sedation failure in the R group was primarily due to the need for more than three additional doses; however, the

Table 4 Logistic Regression Analysis of Risk Factors for Sedation-Related Adverse Events in Pediatric MRI

Clinical Characteristics	β	S.E	X^2	OR (95% CI)	*P*	β (Adjusted)	S.E (Adjusted)	X^2 (Adjusted)	OR (95% CI, Adjusted)	*P* (Adjusted)
Age (years)	0.087	0.116	0.563	1.091 (0.869–1.369)	0.453					
Sex (male vs female)	0.053	0.183	0.084	1.054 (0.737–1.509)	0.772					
Weight (kg)	0.143	0.158	0.819	1.154 (0.846–1.573)	0.365					
ASA classification (I vs II)	−0.134	0.372	0.130	0.875 (0.422–1.813)	0.719					
Examination duration	−0.098	0.137	0.512	0.907 (0.693–1.186)	0.474					
Induction time	−0.563	0.171	10.84	0.569 (0.407–0.796)	0.001	−0.183	0.154	1.418	0.832 (0.616–1.126)	0.234
Sedative agent (remimazolam vs propofol)	−1.327	0.309	18.443	0.265 (0.145–0.486)	<0.001	−0.832	0.361	5.312	0.435 (0.214–0.883)	0.021
Recovery time	0.374	0.153	5.975	1.454 (1.077–1.962)	0.015	0.325	0.134	5.882	1.384 (1.064–1.800)	0.015
Additional drug doses (≥2 vs <2)	0.783	0.326	5.769	2.188 (1.155–4.145)	0.016	0.603	0.187	10.398	1.828 (1.267–2.637)	0.001

Note: Adjusted OR and 95% CI are calculated after adjusting for variables with $P < 0.05$ in univariate logistic regression.

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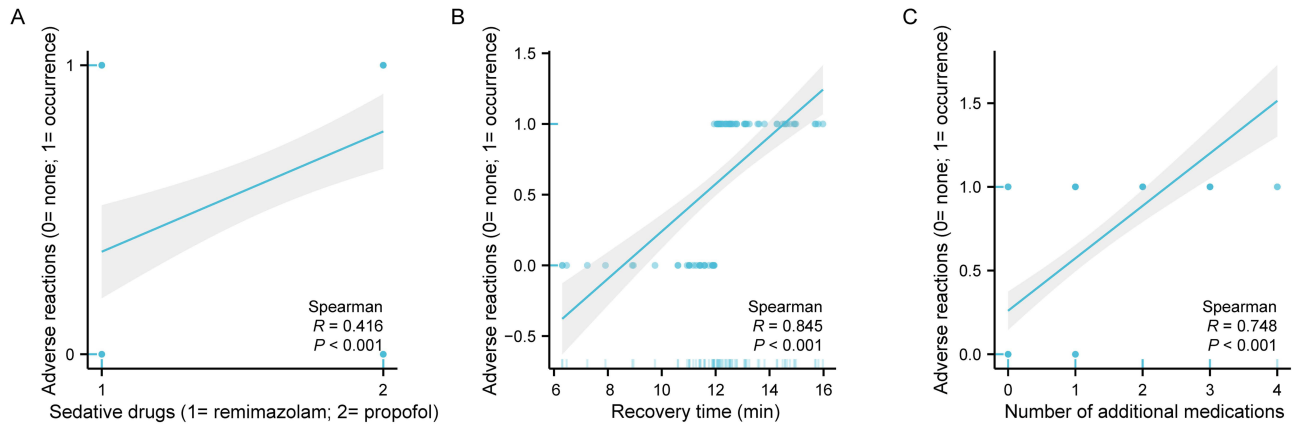

Figure 2 Correlation Analysis Between Adverse Events and Sedative Agent, Recovery Time, and Frequency of Additional Drug Administration. (**A**) Correlation between the choice of sedative agent (remimazolam vs propofol) and the incidence of adverse events. (**B**) Correlation between recovery time and the incidence of adverse events. (**C**) Correlation between the frequency of additional drug administration and the incidence of adverse events.

overall frequency of supplemental dosing was significantly lower in the R group than in the P group, consistent with Table 2. This finding may be partly related to the relatively low induction dose of 0.4 mg/kg remimazolam used in this study. Moreover, differences in induction and recovery times were observed between the two groups. The P group exhibited a shorter induction time, potentially facilitating quicker initiation of surgical procedures, but had a longer recovery time. In contrast, the R group, despite a longer induction time, showed a shorter recovery time, enabling faster postoperative recovery in children. These findings align with previous comparisons of remimazolam and propofol in pediatric painless gastroscopy.[13–15]

Although the reported ED95 of remimazolam for pediatric sedation is 0.673 mg/kg, we deliberately selected a lower induction dose of 0.4 mg/kg in this study. This choice was based on three considerations. First, pediatric patients are more vulnerable to sedative-related adverse events, especially respiratory depression and hemodynamic instability; thus, a conservative dosing strategy was adopted to enhance safety during MRI examinations. Second, remimazolam has rapid onset and short elimination half-life, and our preliminary pilot experience suggested that 0.4 mg/kg was sufficient to achieve the target sedation depth (MOAA/S ≤ 2) in most cases, while reducing the risk of oversedation. Third, the study design permitted supplemental dosing (0.2 mg/kg) as needed, ensuring that adequate sedation could still be maintained throughout the MRI procedure. This stepwise approach allowed us to balance safety with efficacy, and our results confirm that despite the lower initial dose, the overall sedation success rate remained high, with the additional advantage of fewer adverse events and faster recovery compared to propofol.

In our study, pulse oximetry rather than capnography was selected for monitoring. This choice reflects both clinical relevance and feasibility in the MRI setting. Pulse oximetry is a widely accepted, non-invasive technique that directly measures oxygenation, the primary concern in pediatric sedation, whereas capnography, though informative for ventilation, is less practical in this environment. Thus, the use of SpO_2 monitoring provided an effective balance between safety and feasibility for detecting hypoxemia.

One of the major challenges associated with intravenous propofol injection during pediatric head MRI scans is severe hypoxia, which can lead to examination interruption, prolonged procedure time, increased patient risk, and reduced efficiency.[16] In this study, the incidence of hypoxia was significantly higher in the propofol group compared to the remimazolam besylate group. Even after increasing the inhaled oxygen flow, two cases in the propofol group still progressed to severe hypoxia, resulting in examination interruption. Previous studies have shown that procedural sedation with remimazolam does not necessitate unplanned mechanical ventilation.[17] This suggests that remimazolam besylate may be a safer sedative option for pediatric outpatient sedation than propofol. Intravenous injection pain is a common adverse effect of propofol sedation, with an incidence rate ranging from 28% to 85% in children.[18] Lidocaine mitigates this pain through multiple mechanisms, including local anesthesia, inhibition of multisynaptic reflexes in the spinal dorsal horn, and promotion of acetylcholine release in the spinal canal.[19] This research first administered 2% lidocaine at a dose

of 1 mg/kg to reduce propofol injection pain. However, the incidence of injection pain in the propofol group (P group) was still significantly higher than in the remimazolam group (R group). This indicates that remimazolam besylate may improve the comfort of pediatric outpatient sedation. There were no significant differences between the two groups in terms of the incidence of hypotension and bradycardia. These adverse events were transient, of short duration, and did not require pharmacological treatment.

This study has several limitations that should be acknowledged. Firstly, the absence of an anti-magnetic micro-pump and the adherence to routine clinical practices led to the use of intermittent intravenous drug injections rather than continuous infusion. This deviation from the optimal administration method may have influenced the results. Intermittent injections can cause fluctuations in drug levels in the body. For instance, a sudden high concentration during injection may increase the likelihood of adverse reactions, while a low concentration between injections could result in inadequate sedation, potentially affecting the success rate and safety of pediatric MRI examinations.[20] This might help explain some of the observed adverse events and the need for additional drug administrations in both groups. Secondly, the lack of double-blinding is a notable limitation. While the difference in drug appearance justified a single-blind design, the absence of double-blinding may have introduced bias. In a single-blind study, the anesthesiologists were aware of the group assignments, which could have influenced their drug administration, patient monitoring, or interpretation of outcomes. Thirdly, the study was conducted at a single center. Different hospitals may have varying patient populations, anesthesia practices, and MRI equipment, all of which could impact sedation outcomes. For example, the experience level of medical staff in administering sedatives and performing MRI examinations may differ across centers. In a multi-center study, a broader range of factors could be considered, and the results would be more generalizable to a wider pediatric population across various regions. Fourthly, the dosing of remimazolam presents another important limitation. The selected dose of remimazolam in this study was 0.4 mg/kg, which is lower than the reported ED95 (0.673 mg/kg) for pediatric sedation.[13] This dosage discrepancy could be a crucial factor contributing to the higher rate of drug supplementation observed in the remimazolam group. With a suboptimal induction dose, the initial sedation might not have been sufficient to maintain the desired depth of sedation throughout the MRI examination, necessitating additional doses. This not only affects the sedation process but also has implications for the occurrence of adverse events and the overall safety and efficacy of the sedation. The higher supplementation rate could also confound the comparison of sedation success rates and recovery times between the two groups. Future studies should carefully consider the appropriate dosing of remimazolam for pediatric MRI sedation, taking into account the ED95 values and other factors such as patient age, weight, and comorbidities to ensure more accurate and reliable results. Finally, the study did not assess the long-term effects of remimazolam and propofol on pediatric patients. While short-term safety and efficacy were evaluated, the potential long-term impacts on cognitive development, behavior, and other aspects of a child's health remain unknown. Given that repeated exposure to sedatives may have cumulative effects, especially on the developing brain, future studies should investigate these long-term consequences to provide more comprehensive data for clinical decision-making.[3]

Conclusions

In conclusion, although the success rates of sedation in the remimazolam besylate and propofol groups were comparable, remimazolam besylate demonstrated a shorter recovery time and a lower incidence of adverse effects, such as hypoxia and injection pain. These findings suggest that remimazolam besylate is a safe and reliable sedative option for pediatric MRI examinations. Future studies should explore the optimal induction and maintenance dosing of remimazolam for pediatric MRI sedation.

Abbreviations

MRI, Magnetic Resonance Imaging; MOAA/S, Modified Observer's Assessment of Alertness/Sedation Scale; ASA, American Society of Anesthesiologists; SpO_2, Peripheral Oxygen Saturation; SBP, Systolic Blood Pressure; HR, Heart Rate; VIF, Variance Inflation Factor; OR, Odds Ratio; CI, Confidence Interval; SD, Standard Deviation.

Data Sharing Statement

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

Ethics Approval and Consent to Participate

This prospective, randomized, controlled clinical study was approved by the Ethics Committee of Lianyungang Maternal and Child Health Hospital (Approval No. XM2022031), and adhered to the ethical principles outlined in the Declaration of Helsinki. Informed consent was obtained from the parents or legal guardians of all participants prior to study enrollment.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interests in this work.

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