

Original Article

Effects of remimazolam or dexmedetomidine combined with propofol on breathing and hemodynamics in patients with heart disease undergoing transesophageal echocardiography: a prospective randomized study

Lei Bao¹, Yang Zhao¹, Yongjun Zhang¹, Lin Zeng², Hui Zhong¹

¹Department of Anesthesiology, Chengdu Seventh People's Hospital (Affiliated Cancer Hospital of Chengdu Medical College), Chengdu 610213, Sichuan, China; ²Department of Anesthesiology, Shifang People's Hospital, Shifang 618400, Sichuan, China

Received November 3, 2025; Accepted July 20, 2026; Epub September 15, 2026; Published September 30, 2026

Abstract: Objective: To compare the analgesic and sedative effects of remimazolam-propofol versus the traditional analgesic and sedative regimen of dexmedetomidine-propofol on transesophageal echocardiography (TEE) examination. Method: The R group received remimazolam 0.1 mg/kg loading over 10 min, followed by 0.5 mg/(kg·h) infusion. The D group received dexmedetomidine 0.5 µg/kg loading over 10 min, then 0.4 µg/(kg·h) infusion. Both groups received propofol 1 mg/kg initially and 25-75 µg/(kg·min) for maintenance. Sedation onset time, procedure duration, recovery time, hemodynamics, adverse events, patient and sonographer satisfaction were recorded. Result: The demographic variables of the two groups were similar. Compared to the D group, the dosage of propofol in the R group was significantly lower. Compared to the baseline and the R group, the mean arterial pressure and heart rate in the D group were significantly reduced. The satisfaction of ultrasound doctors in the R group was higher than that of the D group. Conclusion: Under TEE conditions, both patient groups were able to achieve the target level of sedation. Compared to dexmedetomidine, remimazolam had the advantage of causing fewer hemodynamic changes and receiving higher satisfaction scores from doctors.

Keywords: Remimazolam, dexmedetomidine, transesophageal echocardiography

Introduction

Transesophageal echocardiography (TEE) and transthoracic echocardiography (TTE) have become fundamental and increasingly important diagnostic tools for evaluating cardiovascular diseases [1]. TTE plays a major role in the preliminary assessment of cardiac function and structure, while TEE allows for clearer visualization of the heart and provides more comprehensive information [2, 3]. However, as an invasive procedure relative to TTE, TEE often induces discomfort including nausea, vomiting, and psychological distress, which may raise the risk of injury to organs along the probe passage [4, 5]. Therefore, many studies have focused on the use of sedatives, which can improve procedural tolerance and success rates and alleviate

the adverse effects of anxiety and stress in these patients [6, 7]. The use of various sedatives may cause respiratory and cardiovascular injury, which still poses a major challenge to patient safety. Thus, safe sedative agents that can maintain stable respiratory and hemodynamic status are urgently needed [8].

Dexmedetomidine, acting by activating pre-synaptic receptors in the central nervous system, is a highly selective α 2-adrenergic agonist with anti-anxiety and analgesic effects. Many researchers have investigated the efficacy of dexmedetomidine, which has been used either alone or in combination with other sedatives including midazolam and propofol, for procedural sedation [9-11].

Remimazolam, a novel short acting GABA_A receptor agonist, belongs to the ultra-short acting benzodiazepine class of central nervous system drugs [12, 13]. It acts on gamma-aminobutyric acid receptors as midazolam does and has a unique metabolic pathway similar to remimazolam [14]. It has a fast onset, short half-life, fast recovery, minimal cardiovascular and respiratory depression, and rarely causes hypotension and respiratory depression [15, 16]. Our previous research has shown that remimazolam has good safety in patients undergoing upper gastrointestinal endoscopy [17].

However, there is relatively little research on the use of remimazolam as a novel ultra-short acting benzodiazepine anesthetic combined to other drugs for TEE examination. The combination of remimazolam and propofol was designed to achieve synergistic and complementary sedation rather than using duplicate sedatives: remimazolam provides stable, safe sedation with minimal hemodynamic and respiratory inhibition, while propofol ensures rapid onset of adequate sedation for invasive TEE procedures. This combined regimen reduces propofol dosage, improves hemodynamic stability, and enhances safety for patients with heart disease, which constitutes the core innovation and key design highlight of this study. This study aimed to investigate the clinical efficacy of remimazolam and dexmedetomidine for sedation during TEE, the primary objective of which is to achieve the target sedation level in a timely manner. In addition, hemodynamic indices, the incidence of oxygen saturation reduction <90%, procedure duration, sedation recovery time, and the satisfaction of ultrasound experts were considered as secondary goals.

Materials and methods

Ethics and informed consent

This study was a prospective, randomized, double-blind study. It was conducted at Shifang People's Hospital. After obtaining approval from the Ethics Committee of Shifang People's Hospital (202425) and China Clinical Trial Registration Center (ChiCTR2400088103), the study was conducted from July 2024 to July 2025.

Participants and study design

A total of 64 patients who were scheduled for TEE at Shifang people's Hospital were enrolled

in this study from July 2024 to July 2025. After 4 refused to participate, 60 eligible participants were included in the final analysis. They were randomly divided into dexmedetomidine group (D group) and a remimazolam group (R group) (**Figure 1**).

The inclusion criteria for this study were patients aged 18-80 years with American Society of Anesthesiologists (ASA) physical status II-III who were diagnosed with atrial septal defect and rheumatic heart disease, including mitral stenosis, mitral regurgitation, aortic stenosis, and aortic regurgitation. Patients with rapid atrial rate, symptomatic bradycardia, congestive heart failure, body mass index >30, esophageal stenosis or tumor or laceration, history of gastrointestinal surgery or dysphagia, active esophagitis, and peptic ulcer disease were excluded.

Diagnostic TEE is performed in the operating room. The patient undergoes preoperative evaluation at the anesthesia clinic before anesthesia. The evaluation includes: medical history collection, physical examination, laboratory and special examinations. All patients provided written informed consent after being informed of the study procedures and interventions. All patients were fasted from solid food for 8 hours and clear liquids for 2 hours. Patients were randomly divided into two groups based on computer-generated numbers: the dexmedetomidine group (D group, n=30) and the remimazolam group (R group, n=30). The numbers were enclosed in sealed opaque envelopes. The main investigator and the echocardiologist who performed the TEE were unaware of the group allocation. All assessors of patient satisfaction and operator satisfaction were blinded to group allocation.

Anesthetic protocol

Remimazolam combined with propofol was used for safer, more stable sedation in TEE. The design highlights were that it was a prospective randomized double-blind controlled trial, measuring the key outcomes (sedation, hemodynamics, recovery, satisfaction) by comparison to dexmedetomidine-propofol to confirm clinical advantages. Upon entering the operating room, patients received routine nasal cannula oxygenation and were monitored for heart rate, blood pressure, pulse oximetry, and body temperature. Before TEE examination, patients in the R group received a loading dose of remima-



CONSORT 2010 Flow Diagram

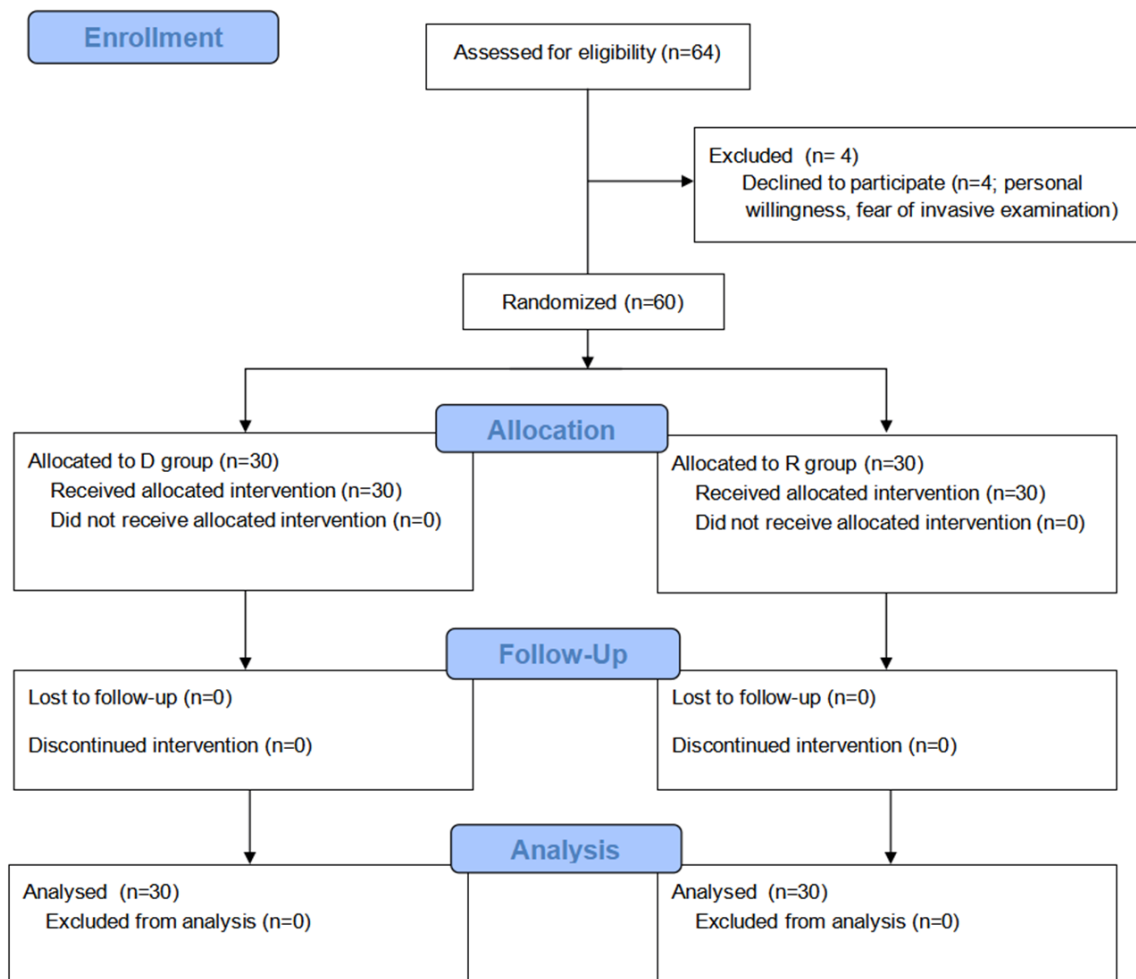


Figure 1. Consort diagram. Initially, 64 patients were randomly assigned to 1 of 2 groups as follows: the dexmedetomidine group (D group) or the remimazolam group (R group). 60 patients (30 in D group and 30 in R group) completed this study.

zolam 0.1 mg/kg, which was infused completely within 10 minutes. Subsequently, continuous intravenous infusion of remimazolam at a dose of 0.5 mg/(kg h) was administered until the end of the procedure. In D group, a loading dose of dexmedetomidine 0.5 µg/kg was infused over 10 minutes, followed by a maintenance infusion of 0.4 µg/kg/h until the end of the proce-

dure. For both groups, the initial propofol dose was 1 mg/kg, with a maintenance infusion of 25-75 µg/kg/min. Once the Ramsay sedation score reached 5, the TEE probe was inserted and echocardiography was initiated. The propofol infusion dose was adjusted according to the patient's sedation level, which was assessed every 5 minutes. If respiratory depression (e.g.,

deep breathing or snoring) occurred, the patient was awakened or given mandibular support; the examination was discontinued and mask ventilation was provided if necessary.

Outcome measures

Vital signs were recorded before administration (T1), before TEE procedure after administration (T2), at the beginning of TEE (T3), 15 minutes after the start (T4), and at the end of TEE (T5). Assess patient satisfaction score (0-10 points, very poor = 0, very good = 10) and Steward recovery score (Consciousness: 0 = asleep; 1 = responds to verbal stimulation; 2 = fully awake; Airway: 0 = requires support; 1 = maintains airway spontaneously; 2 = effective cough; Movement: 0 = no movement; 1 = purposeful movement; 2 = active movement. Total score ranges from 0 to 6; higher scores indicate better recovery). 30 minutes after TEE. The participating examining physicians also evaluated the satisfaction with the anesthesia (0-10 points, very poor = 0, very good = 10). We compared the safety of sedation regimens for the two groups of patients, including the occurrence of respiratory complications (coughing, hiccup during surgery, requiring wake-up and mask pressure oxygen), hypoxemia (pulse oximetry <90%), circulatory complications, and anesthesia efficacy.

Definitions of efficacy indicators: Awakening time: the time from drug discontinuation until the patient responds to simple verbal commands (e.g., eye opening).

Recovery time: the time from drug discontinuation until the Steward recovery score reaches ≥ 4 points.

Steward recovery score: as defined above (0-6 points).

Statistical analysis

In the preliminary study, the time to the target sedation level in the R group was 12.92 (SD=1.2), whereas the mean in the D group was 12.03 (SD=1.11). A two-sample t-test showed that the difference was not significant for the time being, $P=0.102$, Cohen's $d=0.7699$. According to the preliminary research results, the sample size calculation was based on the time to the target sedation level as the primary

outcome. We set $\alpha=0.05$, and power=0.8 was used to determine the study. According to the formula estimate, the effective sample size N was ≈ 26 for each group. Invasive clinical trials often need to recruit more subjects to prevent patients from falling out during follow-up. Based on experience, it was assumed that 10% of participants are lost to follow-up, so each group of samples was adjusted up to $N^*=N/(1-0.1)\approx 29$.

Statistical analysis was performed using SPSS 26.0 for Windows.

Demographic and baseline data (age, BMI, gender, ASA classification, comorbidities) were compared between groups. Normally distributed continuous data were presented as mean $\pm$ standard deviation ($\bar{x} \pm s$) and compared using independent-samples t-test. Categorical data (gender, ASA, comorbidities) were presented as number (percentage) and compared using Pearson χ^2 test.

Primary outcome (time to target sedation level) and secondary continuous outcomes (procedure duration, awakening time, recovery time, Steward recovery score, propofol dosage, hemodynamic indices including HR and MAP at each time point) were analyzed using independent-samples t-test for between-group comparisons.

Hemodynamic variables (HR, MAP) measured at multiple time points (T1-T5) were analyzed using repeated-measures analysis of variance (ANOVA) for within-group comparisons across time points.

Adverse events (hypotension, hypoxemia, auxiliary ventilation, nausea and vomiting, choking cough, hiccup) were categorical variables and compared between groups using Pearson χ^2 test or Fisher's exact test where appropriate.

Satisfaction scores (ultrasound doctor satisfaction, patient satisfaction) were compared between groups using independent-samples t-test. A two-sided $P<0.05$ was considered significant.

Results

Demographic and perioperative data

As shown in **Table 1**, there were no significant differences between the two groups in terms of

Sedation for TEE in heart disease patients

Table 1. Demographic data in the study groups

Index	D group (n=30)	R group (n=30)	χ^2/t	P value
Age (years)	68.73 $\pm$ 9.73	64.17 $\pm$ 10.87	1.712	0.092
Body mass index (kg/m ²)	25.19 $\pm$ 5.4	25.17 $\pm$ 4.29	0.016	0.987
Gender (Male/Female)	17/13	15/15	0.268	0.605
ASA (II/III)	26/4	25/5	0.131	0.718
Diabetes mellitus [n (%)]	5 (16.7%)	4 (13.3%)	0.131	0.718
Hypertension [n (%)]	13 (43.3%)	12 (40%)	0.069	0.793

Note: Data presented as mean $\pm$ standard deviation or patient's number (%). ASA, American Society of Anesthesiology.

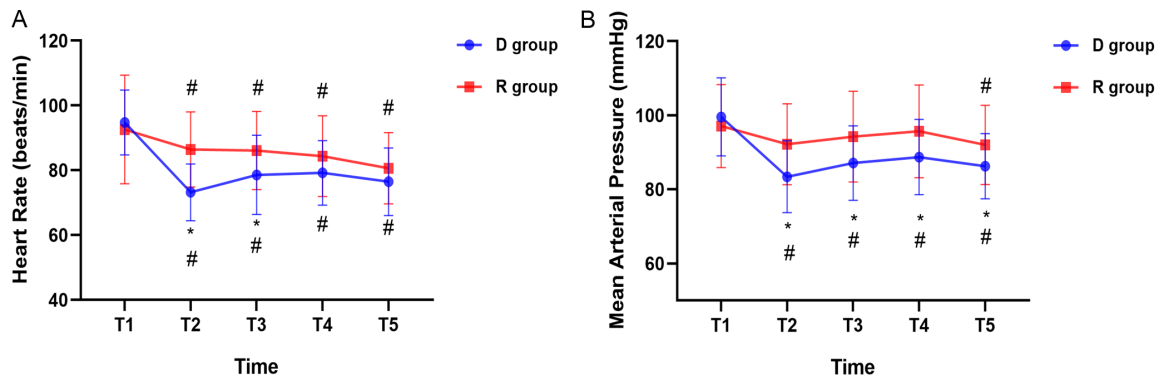


Figure 2. Variables reflecting hemodynamic data at various time points in patients undergoing transesophageal echocardiography with dexmedetomidine or remimazolam. n=30 for each group. A. Changes in the heart rate; B. Mean arterial pressure. #P<0.05 vs. baseline; *P<0.05 vs. D group.

age, gender, body mass index, ASA classification, or comorbidities ($P>0.05$).

Comparison of hemodynamics between the two patient groups

From **Figure 2A**, it can be seen that both groups showed a significant decrease in HR during T2-T5 compared to T1 ($P<0.05$). There was no significant difference in HR between the two groups at T1 ($P>0.05$). At T2 and T3, HR in the R group was higher than that in the D group ($P<0.05$).

Figure 2B shows that, compared to T1, the MAP in the D group significantly decreased during T2-T5, while the MAP in the R group significantly decreased at T5 compared to T1 ($P<0.05$). There was no significant difference in MAP between the two groups at T1 ($P>0.05$). MAP in R group was higher than that in D group at T2, T3, T4, and T5 ($P<0.05$).

The intraoperative and postoperative events during the study are shown in **Table 2**. There were no significant differences between the

two groups in terms of time to reach the target level of sedation, duration of surgery, observation time in the recovery room, and recovery scores ($P>0.05$). The dose of propofol and the recovery time in the R group were significantly shorter than those in the D group ($P<0.05$).

As shown in **Table 3**, there was no significant difference in the incidence of complications and patient satisfaction between the two groups ($P>0.05$). The satisfaction of ultrasound physicians in R group was higher than that of the D group ($P<0.05$).

Discussion

Trans-esophageal echocardiography (TEE) examination is an important diagnostic technique for heart disease. Because of its invasive nature, the procedure often causes severe discomfort in patients, who therefore require adequate sedation and analgesia. In recent years, remimazolam and dexmedetomidine, as novel sedation drugs, have demonstrated their respective advantages when used in combination with traditional propofol during TEE exami-

Sedation for TEE in heart disease patients

Table 2. Intra- and postoperative events in the course of the study

Index	D group (n=30)	R group (n=30)	t	P value
Time to reach RSS 5-6 (min)	12.05 ± 1.06	12.37 ± 1.1	-1.147	0.256
Procedure duration (min)	33.67 ± 6.01	34.17 ± 12.87	-0.193	0.848
Awakening time (min)	7.17 ± 2.52	5.9 ± 2.16*	2.092	0.041
Recovery time (min)	23 ± 9.52	24 ± 11.25	-0.372	0.712
Steward recovery score	5.63 ± 0.85	5.93 ± 0.94	-1.297	0.2
Dosage of propofol (mg)	196.2 ± 46.85	170.88 ± 49.44*	2.038	0.046

Note: Data presented as mean ± standard deviation. RSS, Ramsay sedation score. *Denotes statistically significant difference. *P<0.05 vs. D group.

Table 3. Incidence of complications and satisfaction survey

Index	D group (n=30)	R group (n=30)	χ ² /t	P value
Hypotension [n (%)]	3 (10%)	0	3.158	0.076
Hypoxemia [n (%)]	3 (10%)	2 (6.7%)	0.218	0.64
Auxiliary ventilation [n (%)]	3 (10%)	2 (6.7%)	0.218	0.64
Nausea and vomiting [n (%)]	1 (3.3%)	2 (6.7%)	0.351	0.554
Choking cough [n (%)]	3 (10%)	2 (6.7%)	0.218	0.64
Hiccup [n (%)]	2 (6.7%)	1 (3.3%)	0.351	0.554
Satisfaction of ultrasound doctors	7.43 ± 1.57	8.27 ± 1.11*	-2.393	0.02
Patient satisfaction	9.2 ± 0.85	8.9 ± 0.84	1.375	0.174

Note: Data presented as mean ± standard deviation or patient's number (%). *Denotes statistically significant difference. *P<0.05 vs. D group.

nations. The following discusses the outcomes of these two combined regimens from multiple perspectives.

Our research indicated that the HR of both patient groups decreased after administration compared to before surgery. This may be attributed to propofol reducing cardiac output through inhibiting myocardial contractility and dilating peripheral vessels, as well as potentially suppressing brainstem cardiac vagal neurons, thereby slowing heart rate [18]. The HR of patients in the D group was lower than that of the R group from the time of drug administration until the start of the procedure. This may be attributed to dexmedetomidine's greater ability to reduce sympathetic tone and attenuate intraoperative stress responses compared to remimazolam [19]. From the start until the end of the procedure, the HR of patients in the D group was lower than that of the R group, but the difference between the two groups was not significant. This may be explained by the anatomic proximity of the esophagus to the heart, where probe insertion or movement could directly stimulate the heart. This suggested that the combination of remimazolam and pro-

fol exhibits superior hemodynamic stability. Studies have shown that compared to dexmedetomidine, remimazolam provides better controllability of sedation and a lower incidence of cardiovascular adverse events [20].

This study found that the MAP of patients in the D group after anesthesia was lower than that of before anesthesia and was lower than that of the R group. This may be because dexmedetomidine activates central α₂ receptors to reduce norepinephrine release, resulting in peripheral vasodilation and decreased blood pressure [21]. Dexmedetomidine can also enhance vagal activity, further inhibiting the automaticity of the cardiac sinoatrial node, cause a decrease in heart rate and cardiac output, and indirectly lead to a decrease in blood pressure [22]. In this study, compared to the use of dexmedetomidine, patients treated with remimazolam had more stable blood pressure. This may be attributed to the pharmacologic properties of remimazolam: it is metabolized to an inactive metabolite (CNS7054) through tissue esterases. Its clearance is independent of hepatic, renal function and body weight, and its metabolic rate is sevenfold faster than midazolam,

thus preventing hypotension due to drug accumulation [23]. Previous studies have shown that remimazolam can inhibit norepinephrine release from the locus coeruleus, reduce surgical stress response, and thus maintain circulatory stability [24]. This is consistent with our research findings.

Previous studies have shown that compared to dexmedetomidine, remimazolam exhibits a shorter time to reach the target level of sedation [25]. However, our findings indicate that the time to achieve a Ramsay sedation score of 5 was similar between the two groups. This may be because previous studies administered single-agent medication, whereas both groups in our study received propofol-based combination therapy, resulting in different outcomes. In our trial, the dosage of propofol in the D group was higher than that in R group, indicating that using remimazolam instead of dexmedetomidine can significantly reduce the dosage of propofol during TEE. This finding, consistent with previous research, demonstrates that remimazolam effectively reduces the propofol dosage required during the gastroscopy anesthesia phase [26]. Patients in the remimazolam group had significantly shorter awakening time, suggesting more rapid recovery from sedation, which is consistent with the rapid metabolic characteristics of remimazolam [27]. The recovery scores for patients in the D group were slightly higher than those in the R group, but the difference was not significant. This indicates that dexmedetomidine results in a relatively slow recovery process, which may nevertheless offer a smoother recovery experience. Due to its analgesic effect, patients may experience less discomfort during the recovery phase. However, the bradycardic effect induced by dexmedetomidine may persist during the recovery period, which requires close monitoring by medical staff [28]. For TEE monitoring during cardiac surgery that requires prolonged sedation, the continuous infusion characteristic of dexmedetomidine may actually be an advantage. The reason for the faster recovery of patients in the R group may also be due to the lower dose of propofol used compared to the D group. Additionally, operation time and anesthesia recovery room stay were similar between the two groups, indicating that both drugs possess rapid metabolism and controllable duration without affecting operation or

recovery time. In fact, the duration of surgery was more dependent on factors such as the complexity of the operation and team coordination.

In our study, we found that the satisfaction of operating physicians in the R group was higher than that in the D group. This may be due to the slightly higher incidence of complications in the group patients compared to the R group. This is consistent with one significant advantage of remimazolam being its mild respiratory depression [29]. Since its metabolism is independent of hepatic enzymes and relies on rapid breakdown by tissue esterases, the risk of respiratory depression remains relatively low even in elderly or hepatically/renally impaired patients [30]. Consistent with previous studies, our findings demonstrated that remimazolam exhibits superior safety and fewer complications in elderly patients, which is particularly crucial for outpatient TEE examinations [31]. There was no significant difference in patient satisfaction and complication rates between the two groups. Both groups of patients did not experience serious complications, indicating that both sedatives can be safely used for TEE examination.

The main limitation of this study was that it was conducted in a single center in the operating room of our hospital, which limits the generalizability of the research results to patients in different clinical environments. Another limitation of this study may have been the small sample size, which could partly account for some non-significant results.

Based on our findings and existing evidence, remimazolam-propofol combination was generally superior to dexmedetomidine-propofol in hemodynamic stability, respiratory safety, and recovery speed during TEE examination. However, numerous studies, including our previous work, have demonstrated that dexmedetomidine's advantages in analgesia and organ protection still render it highly valuable for specific clinical scenarios [32, 33].

Acknowledgements

This study was supported by grants from the Key R&D projects in the field of social development in Deyang City (2023SZZ104) and

Chengdu Medical Science Research Project (2025184).

Disclosure of conflict of interest

None.

Address correspondence to: Hui Zhong, Department of Anesthesiology, Chengdu Seventh People's Hospital (Affiliated Cancer Hospital of Chengdu Medical College), Chengdu 610213, Sichuan, China. E-mail: Ztou20260320@163.com

References

- [1] Cury AF, Vieira ML, Fischer CH, Rodrigues AC, Cordovil A, Monaco C, Naccarato GA, Tavares G, Lira Filho EB, Guimarães LA and Morhy SS. Safety of transesophageal echocardiography in adults: study in a multidisciplinary hospital. *Arq Bras Cardiol* 2009; 93: 478-483.
- [2] Aydin A, Yilmazer MS, Gurol T, Celik O and Dagdeviren B. Ondansetron administration before transoesophageal echocardiography reduces the need for sedation and improves patient comfort during the procedure. *Eur J Echocardiogr* 2010; 11: 752-755.
- [3] Ferson D, Thakar D, Swafford J, Sinha A, Sapire K and Arens J. Use of deep intravenous sedation with propofol and the laryngeal mask airway during transesophageal echocardiography. *J Cardiothorac Vasc Anesth* 2003; 17: 443-446.
- [4] Eren G, Dogan Y, Demir G, Tulubas E, Hergunsel O, Tekdos Y, Dogan M, Bilgi D and Abut Y. Hypnosis for sedation in transesophageal echocardiography: a comparison with midazolam. *Ann Saudi Med* 2015; 35: 58-63.
- [5] Gendreau MA, Triner WR and Bartfield J. Complications of transesophageal echocardiography in the ED. *Am J Emerg Med* 1999; 17: 248-251.
- [6] Toman H, Erkilinc A, Kocak T, Guzelmeric F, Savluk OF, Dogukan M and Acar G. Sedation for transesophageal echocardiography: comparison of propofol, midazolam and midazolam-alfentanil combination. *Med Glas (Zenica)* 2016; 13: 18-24.
- [7] José GM, Silva CE, Ferreira LD, Novaes YP, Monaco CG, Gil MA, Linhares RR, Rodrigues MS, Moraes AS and Ortiz J. Effective dose of sedation in transesophageal echocardiography: relation to age, body surface area and left ventricle function. *Arq Bras Cardiol* 2009; 93: 576-581, 623-9.
- [8] Alizadehasl A, Sadeghpour A, Totonchi Z, Azarfarin R, Rahimi S and Hendiani A. Comparison of sedation between dexmedetomidine and propofol during transesophageal echocardiography: a randomized controlled trial. *Ann Card Anaesth* 2019; 22: 285-290.
- [9] Watt S, Sabouri S, Hegazy R, Gupta P and Heard C. Does dexmedetomidine cause less airway collapse than propofol when used for deep sedation? *J Clin Anesth* 2016; 35: 259-267.
- [10] Loh PS, Ariffin MA, Rai V, Lai LL, Chan L and Ramli N. Comparing the efficacy and safety between propofol and dexmedetomidine for sedation in claustrophobic adults undergoing magnetic resonance imaging (PADAM trial). *J Clin Anesth* 2016; 34: 216-222.
- [11] Boriosi JP, Eickhoff JC, Klein KB and Hollman GA. A retrospective comparison of propofol alone to propofol in combination with dexmedetomidine for pediatric 3T MRI sedation. *Paediatr Anaesth* 2017; 27: 52-59.
- [12] Zhang H, Li Z, Mu Z, Wu Y, Zhang S, Zhou Y, Zhang D, Zhao X, Xing W, Wang Y, Lin B, Liang X, Zheng C, Li C and Zhang J. The anionic surfactant sodium dodecyl benzene sulfonate alleviates inflammatory responses in atopic dermatitis via NFκB/MAPK pathways in a STAT3-dependent manner. *Sci Rep* 2025; 15: 28019.
- [13] Chen SH, Yuan TM, Zhang J, Bai H, Tian M, Pan CX, Bao HG, Jin XJ, Ji FH, Zhong TD, Wang Q, Lv JR, Wang S, Li YJ, Yu YH, Luo AL, Li XK, Min S, Li L, Zou XH and Huang YG. Remimazolam tosylate in upper gastrointestinal endoscopy: a multicenter, randomized, non-inferiority, phase III trial. *J Gastroenterol Hepatol* 2021; 36: 474-481.
- [14] Goudra BG and Singh PM. Remimazolam: the future of its sedative potential. *Saudi J Anaesth* 2014; 8: 388-391.
- [15] Oka S, Satomi H, Sekino R, Taguchi K, Kajiwarra M, Oi Y and Kobayashi R. Sedation outcomes for remimazolam, a new benzodiazepine. *J Oral Sci* 2021; 63: 209-211.
- [16] Paton DM. Remimazolam: a short-acting benzodiazepine for procedural sedation. *Drugs Today (Barc)* 2021; 57: 337-346.
- [17] Wu X, Zeng L, Zhang T, Wu W, Tian Y and Dong S. The study of different dosages of remazolam combined with sufentanil and propofol on painless gastroscopy: a randomized controlled trial. *Medicine (Baltimore)* 2023; 102: e34731.
- [18] Tan H, Lou A, Wu J, Chen X and Qian X. Comparison of hypotension between propofol and remimazolam-propofol combinations sedation for day-surgery hysteroscopy: a prospective, randomized, controlled trial. *BMC Anesthesiol* 2024; 24: 360.
- [19] Zeng L, Liu J, Zhang T, Liu Y, Liao L, Chen X and Dong S. Study on the protective mechanism of dexmedetomidine on the liver of perioperative diabetic patients: a randomized controlled trial. *Medicine (Baltimore)* 2022; 101: e30899.

Sedation for TEE in heart disease patients

- [20] Gao S, Wang T, Cao L, Li L and Yang S. Clinical effects of remimazolam alone or in combination with dexmedetomidine in patients receiving bronchoscopy and influences on postoperative cognitive function: a randomized-controlled trial. *Int J Clin Pharm* 2023; 45: 137-145.
- [21] Jayaraj A, Jamale PB and Joshi VM. Fentanyl versus dexmedetomidine during awake-fibre-optic intubation. *Bioinformation* 2025; 21: 418-425.
- [22] Zhang L, Zhang W, Duan C, Hao L, Jing L and Hou X. Analysis of the impact of dexmedetomidine on the vital signs of patients with anxiety at various time intervals upon entering the operating room. *BMC Psychiatry* 2025; 25: 663.
- [23] Ikeda T, Miyoshi H, Kido K, Sumii A, Otsuki S, Kato T, Nakamura R, Narasaki S and Tsutsumi YM. Comparison between single bolus dose administration and continuous infusion of remimazolam for general anesthesia induction in non-cardiac surgery: a single-center prospective randomized controlled trial. *BMC Anesthesiol* 2025; 25: 150.
- [24] Duan M, Yu N, Liu J, Zhao Y, Zhang J, Song S and Wang S. Remimazolam suppresses oxidative stress and apoptosis in cerebral ischemia/reperfusion injury by regulating AKT/GSK-3 β /NRF2 pathway. *Drug Des Devel Ther* 2025; 19: 111-128.
- [25] Hong SW, Park JY, Rhee KY and Kim SH. Comparison emergence of sedation, using dexmedetomidine and remimazolam, in spinal anaesthesia - double blinded randomized controlled trial. *Int J Med Sci* 2024; 21: 1552-1558.
- [26] Wu X, Chen Y, Luo T, Liu Y and Zeng L. The study of remazolam combined with propofol on painless gastroscopy: a randomized controlled trial. *J Perianesth Nurs* 2025; 40: 281-287.
- [27] Chen Y, Cai Y, Yu G, Zhang X, Hu T and Xue R. Safety and efficacy of remimazolam tosylate for sedation during combined spinal-epidural anesthesia for orthopedic procedures: a randomized controlled trial. *BMC Anesthesiol* 2024; 24: 75.
- [28] Morris R, Kuppa SA, Zhu X, Bu K, Han W and Cheng F. The association between dexmedetomidine and bradycardia: an analysis of FDA adverse event reporting system (FAERS) data and transcriptomic profiles. *Genes (Basel)* 2025; 16: 615.
- [29] Terres MT, Assis ML, DA Silveira CB and Amaral S. Remimazolam versus propofol for endoscopy sedation in elderly patients: a systematic review, meta-analysis and trial sequential analysis. *Minerva Anesthesiol* 2024; 90: 775-784.
- [30] Rogers WK and McDowell TS. Remimazolam, a short-acting GABA(A) receptor agonist for intravenous sedation and/or anesthesia in day-case surgical and non-surgical procedures. *IDrugs* 2010; 13: 929-937.
- [31] Zhang Q, Zhao R, Wu Y, Zhang L and Feng Y. Etomidate combined with propofol versus remimazolam for sedation in elderly patients during gastrointestinal endoscopy: a randomized prospective clinical trial. *Drug Des Devel Ther* 2024; 18: 2681-2692.
- [32] Zeng L, Zhao C, Cui C, Liu J, Wang Y, Zhang Y, Dong S and Zhang T. Dexmedetomidine improves DM-induced oxidative stress injury to protect liver function through Nrf2 pathway. *Am J Transl Res* 2023; 15: 1715-1729.
- [33] Wang YC, Wang MJ, Lee CY, Chen CC, Chiu CT, Chao A, Chan WS, Tsai MK and Yeh YC. Effects of perioperative dexmedetomidine infusion on renal function and microcirculation in kidney transplant recipients: a randomised controlled trial. *Ann Med* 2022; 54: 1233-1243.