Available online at www.medicinescience.org

ORIGINAL ARTICLE

Medicine Science International Medical Journal

Medicine Science 2025;14(4):1237-42

Effect of oxygen administration with double nasal cannula on respiratory complications in gastrointestinal endoscopy

Haci Osman Toplu[1], Nurcin Gulhas[1], Mukadder Sanli[1], Duygu Demiroz[1], Ahmet Kadir Arslan[2], Yahya Atayan[3]

[1]İnönü University Faculty of Medicine, Department of Anesthesiology and Reanimation, Malatya, Türkiye
[2]İnönü University Faculty of Medicine Department of Biostatistics and Medical Informatics, Malatya, Türkiye
[3]İnönü University Faculty of Medicine, Department of Gastroenterology, Malatya, Türkiye

Received 30 June 2025; Accepted 28 July 2025
Available online 28 November 2025 with doi: 10.5455/medscience.2025.06.177

Abstract

In the present study, the purpose was to investigate the effect of oxygen therapy applied with a double nasal cannula on desaturation and respiratory complications in cases planned for gastrointestinal endoscopy. A total of 300 patients with ASA I-II, between the ages of 18-65, who were scheduled to undergo gastrointestinal endoscopy, were included in the study. Following routine monitoring, the patients were randomized into 3 groups using the envelope method. Group TK5 (n=100) was administered 5 liters/minute (L/min) preoxygenation with a nasal oxygen cannula for 5 minutes during the procedure and afterwards, 5 L/min oxygen in the same manner. Group TK15 (n=100) was administered 15 L/min preoxygenation with a nasal oxygen cannula for 5 minutes during the procedure and afterwards, 15 L/min oxygen in the same manner. Group CK30 (n=100): 30 L/min preoxygenation with a double nasal oxygen cannula for 5 minutes, and 30 L/min oxygen in the same manner during and after the procedure. The incidence of desaturation was found to be significantly lower in GTK15 (7%) and GCK30 (2%) compared to GTK5 (31%) ($p<0.05$). Advanced desaturation was not detected in any patient in GTK15 and GTK30, while it was detected in 18% of the GTK5 group ($p<0.05$). Severe desaturation was detected in 11% of the GTK5 group, while there was no severe desaturation in the other groups ($p<0.05$). The duration of desaturation was longer in GTK5 than in the other groups. The time to reach 99% oxygen saturation was significantly shorter in the G15 and G30 groups compared to the G5 group ($p < 0.05$). This time was significantly shorter in GCK30 than in GTK15 ($p<0.05$). However, there was a burning sensation in the nose in 30% of the patients in double nasal cannula oxygen applications ($p<0.05$). It was found that oxygen administration with a double nasal cannula had similar effectiveness to single nasal cannula 15 L/min flows in preventing respiratory complications in sedation applications performed for gastrointestinal system endoscopies, and that respiratory complications were significantly reduced at both flow rates compared to 5 L flow rates. It was also found that a single cannula 15 L/min application was better in terms of patient comfort.

Keywords: Gastrointestinal endoscopy, sedation, respiratory complications, oxygen administration

Introduction

Endoscopy procedures associated with the gastrointestinal system are very frequently performed procedures and are usually performed under sedation while preserving spontaneous respiration to increase the quality of the procedure and ensure patient comfort [1,2]. Respiratory depression may develop because of sedation, and upper airway collapse may occur. Also, the endoscope used for the procedure may itself obstruct the airways or may compress the lungs because of intestinal gas insufflation. Because of all these reasons, hypoxemia may develop during gastrointestinal endoscopy at a rate of 26-85% [1]. For this reason, although various methods have been used to prevent desaturation and hypoxemia during gastrointestinal endoscopy, the most common and usable recommendation is to administer standard oxygen [1,2]. Oxygen administration can be performed with many methods, such as nasal cannula, oxygen mask, supraglottic jet ventilation, and noninvasive mechanical ventilation [3,4]. Ventilation with 100% oxygen

CITATION
Toplu HO, Gulhas N, Sanli M, et al. Effect of oxygen administration with double nasal cannula on respiratory complications in gastrointestinal endoscopy. Med Science. 2025;14(4):1237-42.

Corresponding Author: Duygu Demiroz, İnönü University, Faculty of Medicine, Department of Anesthesiology and Reanimation, Malatya, Türkiye
Email: drduygudemiroz@hotmail.com

DOI: 10.5455/medscience.2025.06.177

before the procedure is recommended to prevent hypoxemia. It has been reported that high-flow oxygen therapy can prevent desaturation during laryngoscopy [1]. High-flow oxygen systems, which have recently entered practice, provide humidified and heated oxygen flow of 50-60 liters (L) per minute, unlike normal conventional methods. In this way, they reduce pharyngeal dead space and respiratory resistance, and create positive end-expiratory pressure (2-8 cmH20) [4,5]. However, because of the high cost of these devices and equipment, it is difficult to have them in every institution, or they cannot be taken to operating rooms because they are used in intensive care units. However, classic nasal cannulas are low-cost, easily accessible, and oxygen-delivering equipment [6]. However, their flow rates do not exceed 15 L per minute. During the pandemic period, attempts were made to provide patients with higher oxygen flows by using the equipment in pairs.

For this reason, in the present study, the purpose was to examine the effect of oxygen therapy applied with a double nasal cannula on desaturation and respiratory complications in cases planned for gastrointestinal endoscopy.

Material and Methods

The present study has clinical trial number NCT06273319 and was conducted after approval was obtained from Malatya Clinical Research Ethics Committee (22.11.2023, 2023/75, 1823/75). A total of 324 patients with American Society of Anesthesiologists (ASA) score I-II (upper, lower, both) aged 18-65 who were scheduled for gastrointestinal endoscopy were included in the study. 5 of the patients did not meet the study criteria. 18 of the patients refused to participate in the study. One patient was excluded from the study because his/her basal oxygen saturation was <90% (Figure 1: Flow chart).

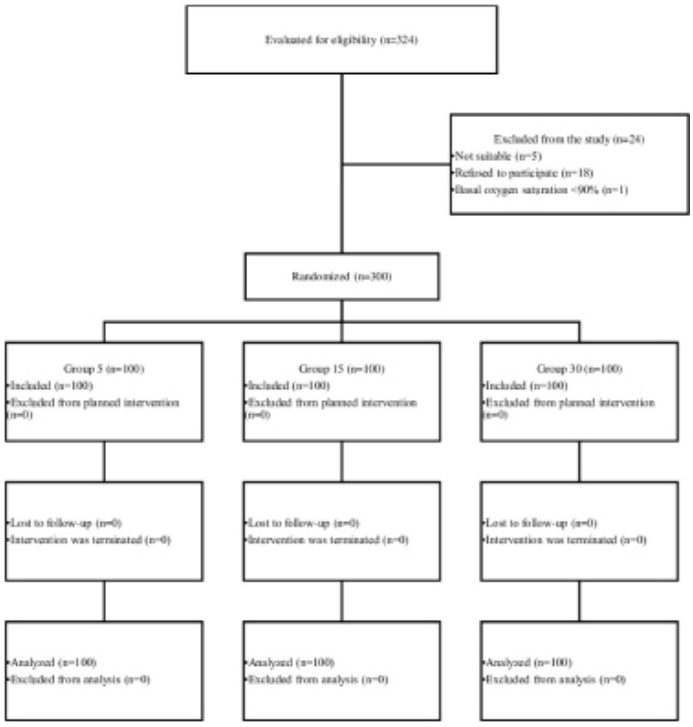

Figure 1. Flow chart

Exclusion Criteria

Patients who had serious cardiac and respiratory diseases, those receiving home oxygen therapy, those with an ASA score of III and above, those with a Body Mass Index (BMI) of 30 and above, those diagnosed with sleep apnea syndrome, those with a STOP BANG questionnaire score of 3 and above, those with an inlet peripheral oxygen saturation of less than 92, those with a tracheotomy, those with nasal obstruction or those with expected difficult intubation or difficult ventilation were excluded from the study.

Anesthesia Management and Study Method

The obstructive apnea (OSA) scores were determined with the preoperative STOP BANG questionnaire. A second nasal cannula oxygen delivery system was kept ready in the intervention room. Following routine monitoring in the patients taken to the intervention room, the head was placed in a 30º semi-recumbent position, and then the patients were randomly divided into 3 groups using the envelope method.

Group TK5 (n=100): 5 minutes of preoxygenation was administered with a nasal oxygen cannula at 5 L/min. Then, 5 L/min oxygen was administered during and after the procedure.

Group TK15 (n=100): 5 minutes of preoxygenation was administered with a nasal oxygen cannula at 15 L/min. Then 15 L/min of oxygen was administered during and after the procedure.

Group CK30 (n=100): Preoxygenation was administered for 5 minutes with a double nasal oxygen cannula at 30 L/min. Then, oxygen was administered at 30 L/min during and after the procedure.

Before the sedation, it was planned for all patients to have an initial peripheral oxygen saturation of 99-100. The time needed for this was recorded. Patients who could not reach these values during the preoxygenation period were excluded from the study. Sedation was provided with 1 milligram/kilogram (mg/kg) propofol, and additional fentanyl (0.5 microgram/kilogram (μg/kg)) in colonoscopies. These doses were repeated when necessary. Desaturation was considered a decrease in peripheral oxygen saturation below 92, and if the duration was over 1 min, mask ventilation was initiated. Situations where saturation fell below 90 were considered as advanced desaturation, and mask ventilation was initiated. Situations where saturation fell below 85 were considered as severe desaturation, and mask ventilation was initiated first, and intubation was planned if severe desaturation continued. Situations where the respiratory rate fell below 6 breaths/min were recorded as bradypnea, and mask ventilation was initiated. The cases where the pulse rate fell below 50 beats/min were defined as bradycardia and treated with atropine 0.5 mg. The decrease in systolic blood pressure by 20% compared to the initial value was accepted as hypotension and treated with ephedrine 10 mg. At the end of the sedation procedure, the patients were taken to the recovery unit, and routine monitoring was applied.

DOI: 10.5455/medscience.2025.06.177

The duration of endoscopy, duration of sedation, amount of propofol and fentanyl, number of desaturation attacks, time to recovery from desaturation, and saturation at the time of leaving the intervention room were recorded for all patients. Side effects such as bradypnea, hypotension, bradycardia, burning sensation in the nose, and desaturation in the recovery unit were recorded. Patients with a postanesthetic Aldrete Recovery Score of 9 and above in the recovery unit were discharged to the ward.

Statistical Analysis

The data used in this study were summarized as mean ± standard deviation and median (interquartile range). The normality of distribution for numerical variables was assessed using the Shapiro-Wilk test. For comparisons involving more than two independent groups in terms of numerical measurements, the Kruskal-Wallis test was applied. Pairwise comparisons were conducted using the Conover test. For comparisons of more than two dependent measurements, the Friedman test was employed. Following the Friedman test, pairwise comparisons were performed using the Bonferroni-adjusted Wilcoxon test. For categorical variables, appropriate chi-square tests were used to compare the groups. A p-value of ≤0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics version 27. Based on the theoretical power analysis findings, at a significance level of 5%, when the test power was 80%, the effect size was 0.3, the alternative hypothesis (H1) and One-Way Analysis of Variance (ANOVA) was used, the total sample size needed to be at least 111 (at least 37 on a group basis) to find a statistically significant difference between the groups.

Results

The demographic characteristics of the groups were similar (Table 1). The incidence of desaturation was statistically significantly lower in GTK15 (7%) and GCK30 (2%) compared to GTK5 (31%) ($p<0.05$). The incidence of desaturation was not different between GCK30 and GTK15 ($p>0.05$). No second desaturation was detected in patients who desaturated. Advanced desaturation was not detected in any patient in GTK15 and GCK30, while it was detected in 18% of the GTK5 group ($p<0.05$). Severe desaturation was detected in 11% of the GTK5 group, and there was no severe desaturation in the other groups ($p<0.05$). The duration of desaturation was 16±32 seconds (sec) in GTK5 compared to the other groups (3±10 sec, 1±5 sec). GTK15 and GCK30 were similar in terms of desaturation times ($p>0.05$). The time to reach saturation 99 was 47±24 sec in G15 and 35±23 sec in G30, which was shorter than G5 (72±43 sec) ($p<0.05$). This time was significantly shorter in GCK30 than in GTK15 (Table 2).

No desaturation was detected in the recovery unit. Endoscopy duration, sedation duration, propofol and fentanyl amounts used were similar in all patients ($p>0.05$). Bradypnea, hypotension, and bradycardia values were similar. However, in double nasal cannula oxygen applications, 30% of patients had a burning sensation in the nose ($p<0.05$) (Table 3).

Table 1. Demographic data

Demographic data	Group 5 (n=100)	Group 15 (n=100)	Group 30 (n=100)	p
Height (cm)	168±8	169±8	167±9	>0.05
Weight (kg)	68±11	68±12	71±14	>0.05
ASA (I/II)	32/68	31/69	22/78	0.251
Gender (F/M)	53/47	61/39	62/38	0,387
BMI(kg/m²)	24.07±2.92	24.06±3.33	25.26±3.89	>0.05
Stop Bang	1±1	1±1	1±1	>0.05
Age (year)	44±15	44±13	48±15	>0.05

A statistically significant difference was not observed in groups

Table 2. Changes in peripheral oxygen saturation of the groups (average ± SD, %, n)

Changes in peripheral oxygen saturation	Group 5 (n=100)	Group 15 (n=100)	Group 30 (n=100)	p
Time to reach 99% saturation	72±43*	47±24+	35±23	<0.001
Desaturation	%31*	%7	%2	<0.001
Duration of desaturation	16±32*	3±10	1±5	<0.001
Advanced desaturation	%18*	0	0	<0.001
Severe desaturation	%11*	0	0	<0.001
SpO2 at the time of leaving the intervention room	51*	81	77	<0.001
Desaturation in the recovery room	0	0	0	
Aldrete score	9±1	9±1	9±0	0,659

*: A statistically significant difference was observed in G5 compared to G30 and G15 ($p< 0.005$); +: A statistically significant difference was observed in G15 compared to G30 ($p< 0.005$)

DOI: 10.5455/medscience.2025.06.177

Table 3. Distribution of developed complications by groups

Complications	Group 5 (n=100)	Group 15 (n=100)	Group 30 (n=100)	p
Bradycardia	1	3	1	>0.05
Bradypnea	1	1	1	>0.05
Hypotension	16	17	12	>0.05
Burning sensation in the nose	0	0	30(%30)*	<0.05

*: A statistically significant difference was observed in G30 compared to G5 and G15 (p< 0.005)

Discussion

In this study, we found that the desaturation rate decreased as the oxygen flow rate increased during gastrointestinal endoscopy procedures in which oxygen was delivered via a nasal cannula. Severe desaturation was not detected when the oxygen flow rate was 15 L or more. Preoxygenation and recovery of desaturation took less time at 15 L and 30 L.

At the end of the procedure, patients who received 15 L or 30 L of oxygen had higher saturation levels when admitted to the recovery room. While the incidence and duration of desaturation were similar at 15 and 30 liters, a burning sensation in the nose occurred at 30 liters.

Dark et al. [9] reported that desaturation occurred in 70% of patients and severe desaturation in 32% of patients undergoing sedation for gastrointestinal endoscopy. However, in contrast to this study, the definition of desaturation in that study was a 4% decrease in saturation. Therefore, their desaturation rate may have been higher than in the present study. One possible reason for the higher rate of severe desaturation in their study is that it only included colonoscopy cases, and preoxygenation was not performed.

Song et al. [10] investigated the effect of ketamine added to propofol on desaturation in endoscopies by administering oxygen at 3 L/min with a single nasal cannula and found the desaturation rate to be 8.2%. The reason for this low rate may be that ketamine, which causes less respiratory depression, was added to sedation.

Yin et al. [11] applied sedation by adding sufentanyl, dexmedetomidine or ketamine to propofol for gastrointestinal endoscopy in elderly patients. Oxygen was administered via a single nasal cannula at a rate of 4 L/min. Similar to the present study, the incidence of hypoxia was high at 40% in the group administered only propofol. Unlike that study, preoxygenation was not performed. The lower incidence of 23% and 7% in the groups added to ketamine and dexmedetomidine may be attributed to the less respiratory depression-inducing effect of ketamine.

Song et al. [10] investigated the effect of adding ketamine to propofol on desaturation during endoscopies. They administered oxygen at 3 L/min with a single nasal cannula and found the desaturation rate to be 8.2%. This low rate may be due to the fact that ketamine, which causes less respiratory depression, was added to the sedation.

Yin et al. [11] used a sedation protocol involving the addition of either sufentanyl, dexmedetomidine, or ketamine to propofol for gastrointestinal endoscopies in elderly patients. Oxygen was administered via a single nasal cannula at a rate of 4 L/min. Similar to the present study, the incidence of hypoxia was high, at 40%, in the group that received only propofol. Unlike the previous study, however, preoxygenation was not performed. The lower incidences of 23% and 7% in the groups that received ketamine or dexmedetomidine, respectively, may be attributed to ketamine's lesser ability to induce respiratory depression.

A single-center, double-blind, randomized, placebo-controlled study conducted in an endoscopy unit demonstrated hypoxia in 22% of the lidocaine group and 39% in the propofol group. In this study, 6 L/min oxygen was administered via nasal cannula for at least 3 minutes during preoxygenation [12]. Unlike our study, lidocaine was used and shown to improve hypoxemia. We believe that 15 L/min oxygen administered via a single cannula may be an alternative when lidocaine is contraindicated. Additional studies are needed to evaluate the effects of lidocaine and 15 L/min oxygen administered via a single cannula on patient outcomes

In a study conducted by Nay et al [13] comparing patients who received HFNC and standard face mask oxygen therapy during sedated gastrointestinal endoscopy procedures performed on patients at risk of hypoxemia, preoxygenation was performed with 40 L/min gas flow and FiO2 1.00 at least 3 minutes before anesthesia induction in the HFNC group or with 100% oxygen with 8 L/min oxygen flow and face mask at least 3 minutes before anesthesia induction in the standard oxygen therapy. Desaturation was considered when the saturation fell below 92 and was detected as 9.4% in the HFNC group and 33.5% in the standard oxygen group. The fact that the study was conducted on patients at high risk of hypoxia may explain the high incidence of desaturation. Patients with underlying cardiac and respiratory diseases, obesity, and OSAS were among the exclusion criteria in the present study. Saturation falling below 85 was defined as severe hypoxia. Severe hypoxia was found to be 3.1% in the HFNC group and 9.6% in the standard oxygen group.

Respiratory complications in sedation performed by gastroenterologists during gastrointestinal endoscopy procedures [14] were examined by Pozin et al. In the study, desaturation was defined as saturation below 90% for less than and more than 60 seconds. Midazolam 1-2 mg, fentanyl 50 μg,

DOI: 10.5455/medscience.2025.06.177

and/or propofol 30-50 mg were applied in induction. In the present study, propofol was started at 1 mg/kg in induction. The rate of saturation <90% for less than 60 seconds was reported to be 12.5%, and the rate of desaturation above 60 seconds was reported to be 12%. The lower rate of desaturation in the present study may be attributed to the lower amount of propofol administered during induction than in the present study. Also, the rate of patients with SpO2 <90% for <60 seconds in the recovery unit was found to be 1.7%, and the rate of SpO2 <90% for >60 seconds was found to be 2.1%. We did not detect desaturation in the recovery unit in the present study. In that study, the high desaturation in the recovery unit may have been because of the lack of oxygen therapy in the recovery unit.

In a study comparing High Flow Nasal Cannula (HFNC) and Standard Nasal Cannula (SNC) oxygen delivery methods in patients receiving anesthesia for advanced esophagogastroduodenoscopy on 262 patients, Mazzeffi et al. [15] started standard oxygen therapy at 6 L/min and HFNC at 20 L/min. In the study where hypoxemia was defined as SpO2 <92% for at least 15 seconds, those with an intervention time of less than 15 minutes were not included in the study. The incidence of hypoxemia was reported to be 33.1% in the SNC group and 21.2% in the HFNO group. The higher incidence of desaturation compared to the present study may be because of the lack of preoxygenation before the procedure and the exclusion criteria for cases with an operation time of less than 15 minutes.

Teng et al. [15] investigated hypoxic events during high-flow nasal cannula and mandibular advancement bite block during sedated esophagogastroduodenoscopy by administering 5 L/min oxygen through a standard nasal cannula, and 100% oxygen was administered at a flow rate of 30 L/min to the HFNC group. Patients were preoxygenated for 5 min before the procedure. Hypoxia was defined as a decrease in oxygen saturation to <90%. The incidence of hypoxia was recorded as 20% in the standard nasal cannula group and 2% in the HFNC group. The lower incidence of hypoxic events in the present study may be because of the mandibular bite block used.

In a multicenter study investigating the effects of propofol sedation with high-flow nasal cannula and standard nasal cannula therapy on the incidence of hypoxia in 1994 patients undergoing gastroscopy, Lin et al. [16] reported that the incidence of subclinical respiratory depression (90% ≤ SpO2 <%95) was 16.3% in the standard oxygen therapy group and 1.6% in the HFNC group. Oxygen was administered at 2 L/min in the standard nasal cannula group and at 60 L/min in the HFNC group at 100% FiO2. The fact that the procedure time was short, 5.01 min in the standard oxygen therapy group and 5.14 min in the HFNC group in that study, may explain the low rate of hypoxia according to our results.

Berzin et al. [17], investigating the side effects of sedation in ERCP performed by an anesthesiologist, reported hypoxia as a saturation below 85%. The incidence of hypoxia was determined to be 12.5% after 528 ERCP procedures in 438 patients. Since we defined the desaturation limit recommended by Sumit et al. [18], for patient safety as below 92% in our study, we believe that lower results were obtained compared to this study.

In the present study, we included patients with Stop BANG questionnaire scores below 3. Not including patients with high Stop BANG scores was one of the limitations of the present study. The fact that blood gas values were not studied was also a limiting factor. Since HFNO was not available in our clinic, we could not include these flows in the present study. This was another limitation of the study.

Conclusion

In conclusion, it was found that oxygen administration with a double nasal cannula has similar effectiveness to single nasal cannula 15 L flows in preventing respiratory complications in sedation applications performed for gastrointestinal system endoscopies, and that respiratory complications were significantly reduced in both flow rates compared to 5 L flow rates. We detected that a single 15 L cannula application was better in terms of patient comfort. We believe that more comprehensive studies are needed on the subject.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
The present study has clinical trial number NCT06273319 and was conducted after approval was obtained from Malatya Clinical Research Ethics Committee (22.11.2023, 2023/75, 1823/75).

References

1. Kehlet H, Wilmore DW. Multimodal strategies to improve surgical outcome. Am J Surg. 2002;183:630–41.
2. Karaman Y, Uluer MS, Beşir A, Zunal SO. Turkish Society of Anesthesiology and Reanimation (TARD) Non-Operating Room Anesthesia Applications Guideline Guideline. Turkish Society of Anesthesiology and Reanimation (TARD). https://akademi.tard.org.tr. Mar. 2022.
3. Pregler JL, Kapur PA. The development of ambulatory anesthesia and future challenges. Anesthesiol Clin North Am. 2003;21:207–28.
4. Hensel M, Schwenk W, Bloch A, et al.The role of anesthesiology in fast track concepts in colonic surgery. Anaesthesist. 2006;55:80–92.
5. Herman AD, Jaruzel CB, Lawton S, et al. Morbidity, mortality, and systems safety in non-operating room anaesthesia: a narrative review. Br J Anaesth. 2021;127:729–44.
6. Wong T, Georgiadis PL, Urman RD, Tsai MH. Non-operating room anesthesia: patient selection and special considerations. Local Reg Anesth. 2020;13:1-9.
7. Metzner J, Posner KL, Domino KB, et al. The risk and safety of anesthesia at remote locations: the US closed claims analysis. Curr Opin Anaesthesiol. 2009;22:502–8.
8. Youn AM, Ko YK, Kim YH, et al. Anesthesia and sedation outside of the operating room. Korean J Anesthesiol. 2015;68:323.
9. Dark DS, Campbell DR, Wesselius LJ. Arterial oxygen desaturation during gastrointestinal endoscopy. Am J Gastroenterol. 1990;85:1317.

DOI: 10.5455/medscience.2025.06.177

10. Song N, Yang Y, Zheng Z, et al. Effect of esketamine added to propofol sedation on desaturation and hypotension in bidirectional endoscopy. JAMA Netw Open. 2023;6:2347886.

11. Yin S, Hong J, Sha T, et al. Efficacy and tolerability of sufentanil, dexmedetomidine, or ketamine added to propofol-based sedation for gastrointestinal endoscopy in elderly patients: A prospective, randomized, controlled trial. Clin Ther. 2019;41:1864-77

12. Qi XR, Qi YX, Zhang K, et al. Intravenous lidocaine decreased oxygen-desaturation episodes induced by propofol-based sedation for gastrointestinal endoscopy procedures: a prospective, randomized, controlled trial. BMC Anesthesiol. 2025;25:27.

13. Nay MA, Fromont L, Eugene A, et al. High-flow nasal oxygenation or standard oxygenation for gastrointestinal endoscopy with sedation in patients at risk of hypoxaemia: a multicentre randomised controlled trial (ODEPHI trial). Br J Anaesth. 2021;127:133–42.

14. Pozin IE, Zabida A, Nadler M, et al. H. Respiratory complications during recovery from gastrointestinal endoscopies performed by gastroenterologists under moderate sedation. Clin Endosc. 2023;56:188–93.

15. Teng WN, Ting C, Wang YT, et al. High-flow nasal cannula and mandibular advancement bite block decrease hypoxic events during sedative esophagogastroduodenoscopy: A randomized clinical trial. Biomed Res Int. 2019;2019:1-7.

16. Lin Y, Zhang X, Li L, et al. High-flow nasal cannula oxygen therapy and hypoxia during gastroscopy with propofol sedation: a randomized multicenter clinical trial. Gastrointest Endosc. 2019;90:591–601.

17. Berzin TM, Sanaka S, Barnett SR, et al. A prospective assessment of sedation-related adverse events and patient and endoscopist satisfaction in ERCP with anesthesiologist-administered sedation. Gastrointest Endosc. 2011;73:710–7.

18. Sumit RM, Dean T, Eurich, JMG, et al. Oxygen Saturations Less than 92% Are Associated with Major Adverse Events in Outpatients with Pneumonia: A Population-Based Cohort Study. Clinical Infectious Diseases. 2011;52:325-31.