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Efficacy of nasal clips combined with nasal cannulas in preventing hypoxemia during gastrointestinal endoscopy with sedation: a randomized controlled trial

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Abstract

Background Gastrointestinal endoscopy with sedation is frequently complicated by hypoxemia. Nasal cannulas have limitations in eliminating hypoxemia. We hypothesized that the combination of nasal clips and nasal cannulas would improve the inspired oxygen concentrations and prevent hypoxemia compared with the use of nasal cannulas alone.

Methods A total of 600 adult patients were randomly assigned to receive supplemental oxygen through single-lumen nasal cannulas or through the combination of nasal clips and nasal cannulas. The primary outcome was the incidence of hypoxemia. Additionally, subclinical respiratory depression and severe hypoxemia, duration of hypoxemia, lowest SpO_2 level, measures to increase oxygen saturation level, and adverse events such as cough and hiccups were compared as secondary outcomes.

Results Three hundred patients in the nasal clip group and 296 patients in the nasal cannula group were included in the intention-to-treat analysis. Nasal clips significantly decreased the incidence of hypoxemia from 25.0–17.7%(*RR* = 0.707, 95% CI = 0.516 to 0.967, *P* = 0.029). The median and interquartile range of lowest SpO_2 in the nasal clip group (96 [92 to 98]) was significantly greater than that in the nasal cannula group (95 [89 to 97]; median difference = 1.000, 95% CI = 0.000 to 2.000, *P* = 0.004). No significant differences were found between the two groups in subclinical respiratory depression or severe hypoxemia, duration of hypoxemia, adverse events or measures taken to increase oxygen saturation.

Conclusions The combination of nasal clips and cannulas reduces hypoxemia during gastrointestinal endoscopy with sedation, demonstrating a significant advantage over the sole use of nasal cannulas, with tolerable adverse events.

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Trial registration Chinese Clinical Trial Registry (ChiCTR2200065407).
Keywords Nasal clip, Nasal cannula, Hypoxemia, Gastrointestinal endoscopy, Sedation

Background

Endoscopy is an important method for diagnosing gastrointestinal diseases [1]. However, due to the discomfort associated with conventional gastrointestinal endoscopy, it is often performed under sedation, which necessitates the preservation of spontaneous breathing. A recent survey conducted across 2758 hospitals in China revealed that sedation was utilized in 47.9% of gastroscopies and 49.3% of colonoscopies performed at these facilities [2]. Among the sedative agents, Propofol, a short-acting intravenous anesthetic, is commonly employed worldwide during endoscopic procedures. It not only enhances patient acceptance but also improves the diagnostic accuracy of gastrointestinal endoscopy [3]. However, propofol-based sedation often accompanies respiratory suppression in a dose-dependent manner [4]. In addition, patients under sedation may suffer upper airway collapses and even obstructions [5]. These adverse effects increase the risk of hypoxemia in patients undergoing gastrointestinal endoscopy with sedation.

A previous study have suggested that the risk of hypoxemia can be reduced by supplemental oxygen [6]. Nasal cannulas, the most commonly used devices for oxygen inhalation, possess inherent limitations in preventing hypoxemia, with an incidence of hypoxemia ranging from 9.0 to 45.2% in patients inhaling oxygen through nasal cannulas during gastrointestinal endoscopy sedation [7]. High-flow nasal cannulas appear to be superior to conventional nasal cannulas due to their higher fraction of inspired oxygen concentrations and small positive end-expiratory pressure [8]. And previous systematic reviews have shown the beneficial effect of high-flow nasal cannulas for the prevention of hypoxemia [7, 9–11]. In addition, nasal masks and supraglottic jet ventilation via the Wei nasal jet tube have also been shown to reduce the incidence of hypoxemia [12–14]. Wang et al. successfully used bilevel positive airway pressure therapy to prevent hypoxemia in patients with obstructive sleep apnea during gastroscopy with sedation [15]. However, these methods require specialized equipment that poses high technical and economic demands, making their routine utilization challenging in most hospitals. Consequently, identifying an efficient, readily implementable, and economically feasible approach to correct hypoxemia during gastrointestinal endoscopy sedation remains crucial.

During our routine sedation work, we observed that patients receiving supplemental oxygen through single-lumen nasal cannulas lost oxygen through their nostrils. Thus, we hypothesized that the combination of a nasal clip, originally intended for swimming and designed to clip the nose to prevent water from entering through the nostrils during underwater activities, with a nasal cannula could prevent oxygen from escaping. This combination could potentially increase inspired oxygen concentrations and reducing the risk of hypoxemia in patients undergoing gastrointestinal endoscopy with sedation. This study was a prospective, randomized, controlled clinical trial aiming to validate this hypothesis.

Methods

Study design and ethics

This prospective randomized controlled clinical trial was approved by the Medical Ethics Committee of Taizhou Enze Medical Centre (Group) Enze Hospital, Taizhou, Zhejiang, China (approval no. K20220307) on 28 March 2022. All participants provided written informed consent before participation. The trial followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines and was registered before patient recruitment at the Chinese Clinical Trial Registry (registration no. ChiCTR2200065407; date of registration: November 4, 2022).

Patient recruitment and exclusion criteria

Patient recruitment was conducted at the Endoscopic Centre of Taizhou Enze Medical Centre (Group) Enze Hospital. The inclusion criteria were as follows: (i)outpatients undergoing gastrointestinal endoscopy (upper, lower, or both); (ii)aged 18 years and above; (iii)ASA classification I-III; (iv)agreement to participate in the trial and sign the informed consent form. The exclusion criteria were as follows: (i)history of upper respiratory tract infection in the past week; (ii)severe chronic obstructive pulmonary disease or acute attack of asthma; (iii)baseline oxygen saturation less than 90% when inhaling air; (iv) history of allergy to eggs, soy, albumin or sedatives; (v) nasal obstruction and cannot effectively inhale oxygen through the nose; (vi)pregnancy or lactation.

Study outcomes

The primary outcome of this study was the incidence of hypoxemia (SpO_2<90% at any given time). The secondary outcomes included the following: (i) subclinical respiratory depression (SpO_2<95% at any given time); (ii) severe hypoxemia (SpO_2<75% at any given time or a duration of SpO_2<90% for >60 s); (iii) duration of hypoxemia (only analyzed in participants who experienced hypoxemia); (iv) lowest SpO_2 level; (v) measures of raising the oxygen saturation level, such as jaw lift, increased oxygen flow rate, abdominal thrust (which force the diaphragm

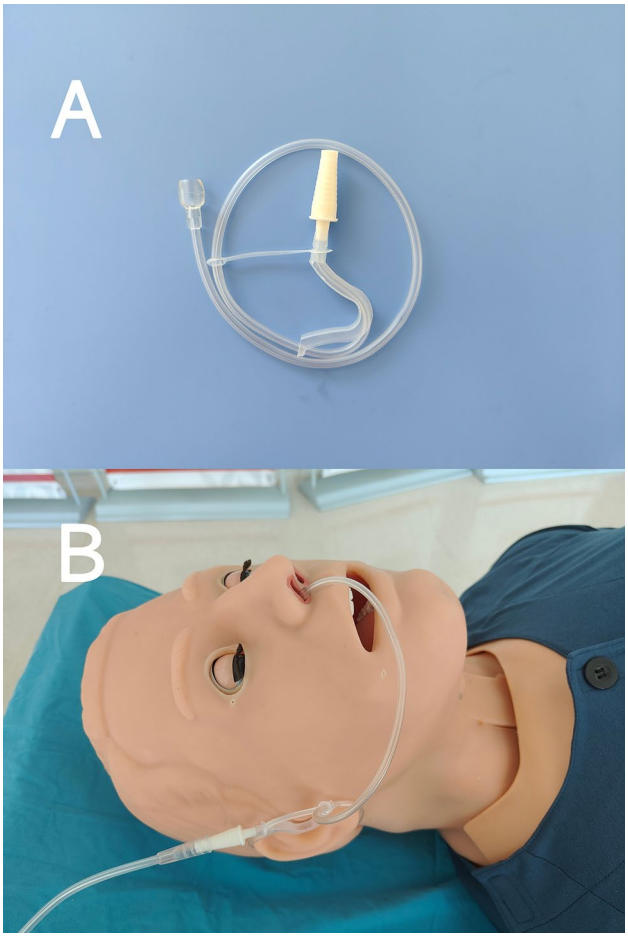

Fig. 1 **A**, Nasal cannula. **B**, Depiction of nasal cannula use

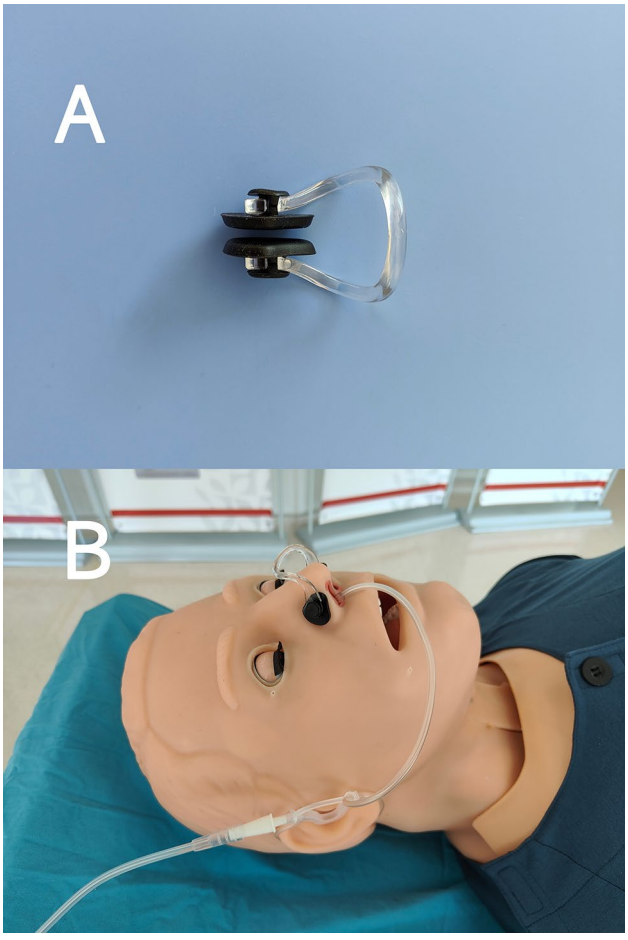

Fig. 2 **A**, Nasal clip. **B**, Depiction of nasal clip use

upward to expel air from the lungs, followed by passive air inhalation as the diaphragm returns to its natural position) [16], mask ventilation and tracheal intubation; and (vi) adverse events, including cough and hiccups.

Randomization and blinding

All eligible participants were randomly divided into nasal clip and nasal cannula groups using a simple randomization sequence generated by SPSS software (version 22.0, IBM) at a 1:1 ratio by an independent researcher who was not involved in the follow-up research. The allocation was concealed using sequentially numbered, sealed and opaque envelopes. Envelope information was opened only by anesthetists when it was time to allocate the intervention. The anesthetists, participants and data recorders could not be blinded in this study, because the use of nasal clips was visible. However, the independent researcher who performed the statistical analysis was blinded.

Study procedure

All participants were required to fast for at least 8 h and were prohibited from drinking for at least 4 h prior to sedation. Venous access was established in the preparation room. Before the examination, all of the participants were placed in the left decubitus position, and then blood pressure, SpO_2, and heart rate were routinely monitored. Afterwards, preoxygenation was started. In the nasal cannula group, single-lumen nasal cannulas were used for oxygen inhalation, with the thicker tip of the cannula being precisely positioned just within the nostril (Fig. 1). In the nasal clip group, nasal clips were used to clip the noses besides nasal cannulas (Fig. 2). All participants received supplemental oxygen at an initial oxygen flow rate of 2 L/min. Sedation induction was performed by the intravenous administration of sufentanil (5 ug) and propofol (1.5-2 mg/kg) by anesthetists after 2 min of preoxygenation. The depth of sedation was assessed by anesthetists according to the Ramsay Sedation Scale [17]. Procedures started when the Ramsay score reached 5 or higher. Sedation was maintained with a continuous infusion of propofol (6 to 8 mg/kg/h). Trained researchers

who were familiar with the study protocol monitored the participants, in collaboration with the anesthetists. These researchers were responsible for recording the lowest SpO2 value observed within each minute. Whenever an episode of SpO2 < 90% occurred, the researcher initiated a timer to record the duration of hypoxemia. The final recorded duration of hypoxemia represented the sum of all hypoxemic episodes for each patient. The anesthetists, on the other hand, were responsible for implementing measures to correct hypoxemia. And anesthetists were suggested correcting hypoxemia according to the following steps when oxygen desaturation occurred: (i)SpO_2<95%: opening the airway with a Jaw lift; (ii)SpO_2<90%: increasing the oxygen flow rate from 2 to 6 L/min; (iii)SpO_2<85% or a duration of SpO_2<90% for>30 s: abdominal thrust (2 cm below the xyphoid process) at a rate of 30 compressions per minute with a compression depth of 2 ~ 3 cm. (iv)SpO_2<80% or a duration of SpO_2<85% for>30 s: mask ventilation. If the aforementioned measures proved ineffective at increasing the oxygen saturation levels, the anesthetists had to determine whether to proceed with endotracheal intubation. All anesthetists possessed a high level of training and were well acquainted with the procedures involved in this study.

Statistical analysis

Statistical analysis was performed in accordance with the intention-to-treat principle, using SPSS software (version 22.0, IBM) by a blinded statistician. A per-protocol analysis was also performed as a sensitivity analysis. The Shapiro-Wilk normality test was used to examine whether the continuous data fit a normal distribution. Normal distributed data are expressed as the mean ± standard deviation ($x \pm s$) with Student's t test for comparison, while nonnormally distributed data are expressed as the median and interquartile range (IQR) with Mann-Whitney U test for comparison. Mean or median differences with 95% confidence intervals (CIs) were also calculated for continuous data depending on the distribution. Dichotomous data are expressed as numbers and percentages with Fisher exact or Chi-squared tests for comparison, as appropriate. A relative risk (RR) was calculated with 95% CI. A P value of < 0.05 ($P < 0.05$) was considered to indicate statistical significance.

The baseline characteristics were compared between groups using standardized differences, and differences > 1.96 sqrt[2/N] were considered unbalanced [18]. In this study, standardized differences exceeding 16.0% were considered unbalanced, with $N = 600$. To investigate the impact of potential confounding factors on the primary outcome, a post-hoc logistic regression analysis was conducted to calculate the odds ratios (ORs) before and after adjustment. Initially, a univariate logistic regression analysis was employed to screen for factors associated with the primary outcome, with a significance level of $P < 0.05$ considered indicative of relevance. Subsequently, a multivariate logistic regression analysis was performed on these selected factors.

Sample size

The sample size was calculated using the 'pwr' package in R software (version 4.1.3). According to a previous study [14], we assumed that a nasal clip combined with a nasal cannula would achieve a reduction for the incidence of hypoxemia from 28–18% compared with a nasal cannula only. We used Cohen's h statistic specific for proportions to quantify the effect size, resulting in an effect size of 0.24, calculated by the 'ES.h' function of the 'pwr' R package. With an $\alpha = 0.05$, a power of 80% and a 1:1 ratio between groups, we estimated that 275 participants per group would be needed. Based on a 10% dropout rate, a total of 600 participants (300 in each group) were ultimately required to complete the study. The specific parameters used in the sample size calculation were: pwr.2p.test (h = ES.h(0.28, 0.18), sig.level = 0.05, power = 0.8, alternative='two.sided').

Results

Demographic and clinical characteristics

The flow diagram of patient selection is illustrated in Fig. 3. A total of 631 patients were screened for enrolment initially and 31 were excluded (23 met the exclusion criteria and 8 declined to participate). The recruitment process started in April 2023 and ended in June 2023 as planed after 600 eligible patients were enrolled, and these patients were randomized into two groups. In the nasal clip group, 3 patients did not receive the allocated intervention (2 had a history of rhinoplasty and 1 patient failed to wear the nasal clip properly), and 6 patients discontinued the intervention (2 experienced mild epistaxis during the procedure and 4 violated the trial protocol). In the nasal cannula group, 4 patients did not receive the allocated intervention (1 cancelled procedure and 3 cancelled sedations) and 4 patients discontinued the intervention because of protocol violation. Ultimately, 300 patients in the nasal clip group and 296 in the nasal cannula group were included in the intention-to-treat analysis. The demographic and clinical characteristics are presented in Table 1, with all standardized differences less than 16.0%.

Primary and secondary outcomes

The primary and secondary outcomes are presented in Table 2. Compared with that in the nasal cannula group, the incidence of hypoxemia significantly decreased from 25.0 to 17.7% ($RR = 0.707$, 95% CI = 0.516 to 0.967, $P = 0.029$) in the nasal clip group. However, no

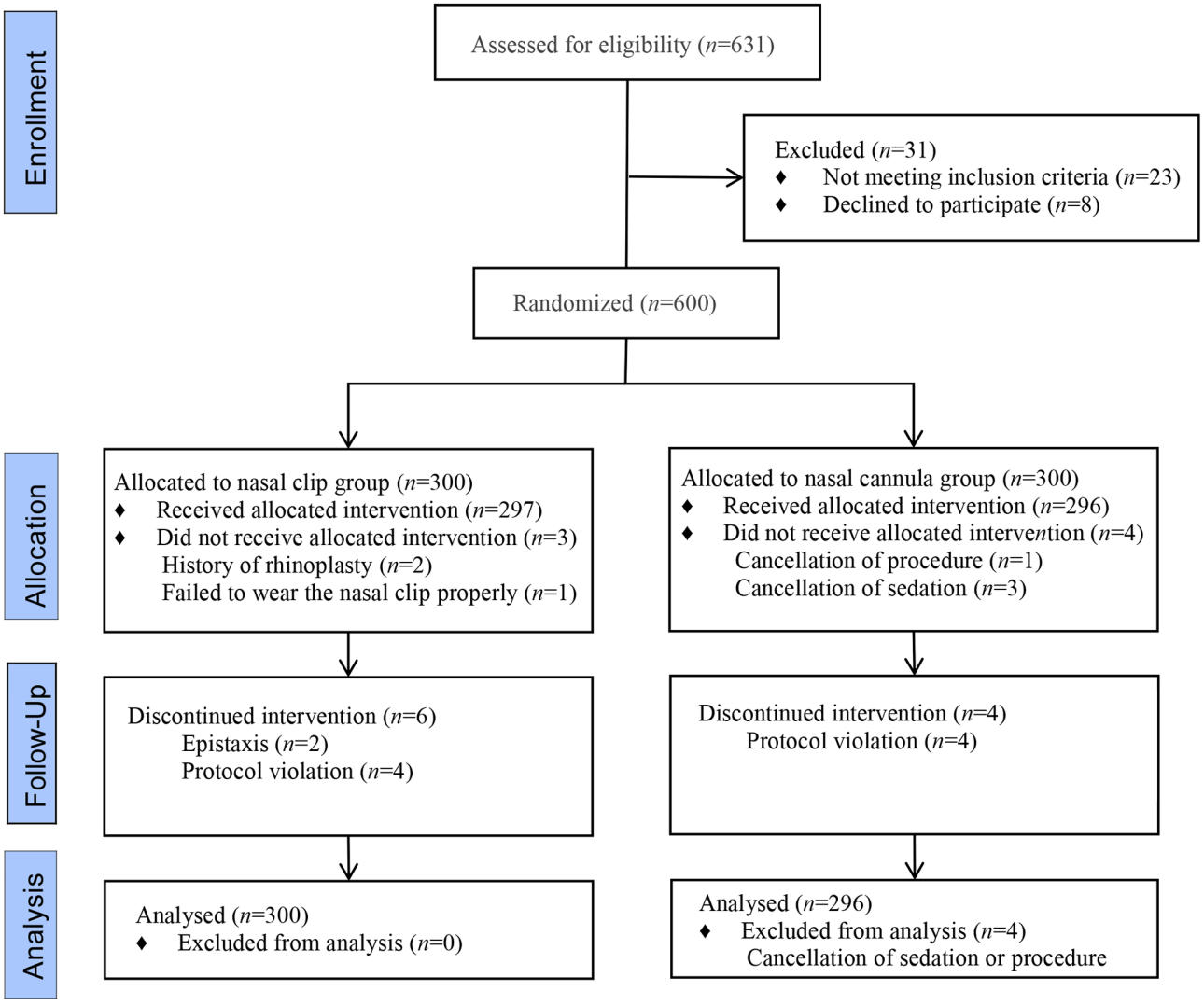

Fig. 3 CONSORT diagram of patient selection

statistically significant differences were found between the nasal clip and nasal cannula groups in terms of the incidence of subclinical respiratory depression (42.0% vs. 50.0%, respectively; *RR* = 0.840, 95% CI = 0.705 to 1.001, *P* = 0.059) or severe hypoxemia (6.3% vs. 5.4%, respectively; *RR* = 1.172, 95% CI = 0.615 to 2.234, *P* = 0.630). The lowest SpO_2 in the nasal clip group (96 [92 to 98]) was significantly greater than that in the nasal cannula group (95 [89 to 97]; median difference = 1.000, 95% CI = 0.000 to 2.000, *P* = 0.004). The duration of hypoxemia was only analyzed for participants who experienced hypoxemia, and no statistically significant differences were found between the nasal clip (42 [17 to 78]) and nasal cannula groups (27 [12 to 54]; median difference = 7.000, 95% CI= -2.000 to 20.000, *P* = 0.155). A total of 126 participants in the nasal clip group and 148 participants in the nasal cannula group who experienced subclinical respiratory depression had taken measures to increase oxygen saturation levels, and all of them had been lifted the jaw to open airway with no statistically significant differences (42.0% vs. 50.0%, respectively; *RR* = 0.840, 95% CI = 0.705 to 1.001, *P* = 0.059). In the nasal clip group, 53 participants (17.7%) increased the oxygen flow rate to correct hypoxemia which was fewer than those increased in the nasal cannula group (69, 23.3%). However, there were no significant differences between the two groups (*RR* = 0.758, 95% CI = 0.550 to 1.044, *P* = 0.088). There were no significant differences between nasal clip and nasal cannula groups in abdominal thrust (4.0% vs. 4.1%, respectively; *RR* = 0.987, 95% CI = 0.451 to 2.161, *P* = 0.973) or in mask ventilation (1.0% vs. 0.3%, respectively; *RR* = 2.960, 95% CI = 0.310 to 28.294, *P* = 0.625). No participants required tracheal intubation throughout the trial. The two groups had no significant differences in the incidence of cough or hiccups.

Table 1 Baseline characteristics for the for the intention-to-treat population

Characteristics	Nasal clip Group, *n* = 300	Nasal cannula Group, *n* = 296	Standardize difference, %[a]
Age, median (IQR), year	52(41 to 60)	53(44 to 61)	5.3
Male, *n* (%)	146(48.7)	156(52.7)	8.0
BMI, median (IQR), kg/m^{-2}	23.36(21.81 to 25.88)	23.88(21.21 to 25.98)	2.9
SBP, median (IQR), mmHg	134(122 to 147)	133(120 to 150)	0.4
DBP, median (IQR), mmHg	79(72 to 86)	78(72 to 88)	8.2
Basal SpO_2, median (IQR), %	97(97 to 98)	97(97 to 98)	6.3
ASA classification, median (IQR)	2(2 to 2)	2(2 to 2)	7.9
-I, *n* (%)	42(14.0)	51(17.2)	
-II, *n* (%)	255(85.0)	242(81.8)	
-III, *n* (%)	3(1.0)	3(1.0)	
STOP-Bang Questionnaire, median (IQR)	2(1 to 2)	2(1 to 3)	2.8
-Score 0–2, *n* (%)	226(75.3)	219(74.0)	
-Score 3–4, *n* (%)	71(23.7)	76(25.7)	
-Score 5–8, *n* (%)	3(1.0)	1(0.3)	
Procedure type			
-Upper gastrointestinal endoscopy, *n* (%)	44(14.7)	57(19.3)	12.3
-Lower gastrointestinal endoscopy, *n* (%)	40(13.3)	29(9.8)	11.0
-Combined upper and lower endoscopy, *n* (%)	216(72.0)	210(70.9)	2.4
Procedure time, median (IQR), min	16(12 to 19)	16(12 to 19)	7.4
Recovery time, median (IQR), min	10(8 to 15)	11(8 to 15)	6.5
Total propofol dosage, median (IQR), mg	260(200 to 300)	260(210 to 300)	5.2

IQR, interquartile range; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO2, saturation of peripheral oxygen

[a]The difference between the groups divided by the pooled standard deviation. A value exceeding 16.0% is considered to indicate significant difference

Table 2 Outcomes for the intention-to-treat population

Outcomes	Nasal clip Group *n* = 300	Nasal cannula Group *n* = 296	RR/ median difference (95% CIs)	*P*
Primary outcome				
Hypoxemia, *n* (%)	53(17.7)	74(25.0)	0.707(0.516 to 0.967)	0.029[a]
Secondary outcomes				
Subclinical respiratory depression, *n* (%)	126(42.0)	148(50.0)	0.840(0.705 to 1.001)	0.059[b]
Severe hypoxemia, *n* (%)	19(6.3)	16(5.4)	1.172(0.615 to 2.234)	0.630[a]
Duration of hypoxemia, median (IQR), s (Only 121 patients with hypoxemia were analyzed)	42(17 to 78)	27(12 to 54)	7.000(-2.000 to 20.000)	0.155[c]
Lowest SpO_2, median (IQR), %	96(92 to 98)	95(89 to 97)	1.000(0.000 to 2.000)	0.004[c]
Measures of raising oxygen saturation level, *n* (%)	126(42.0)	148(50.0)	0.840(0.705 to 1.001)	0.059[b]
-Jaw lift, *n* (%)	126(42.0)	148(50.0)	0.840(0.705 to 1.001)	0.059[b]
-Increase the oxygen flow rate, *n* (%)	53(17.7)	69(23.3)	0.758(0.550 to 1.044)	0.088[a]
-Abdominal thrust, *n* (%)	12(4.0)	12(4.1)	0.987(0.451 to 2.161)	0.973[a]
-Mask ventilation, *n* (%)	3(1.0)	1(0.3)	2.960(0.310 to 28.294)	0.625[a]
-Tracheal intubation, *n* (%)	0(0)	0(0)	NA	NA
Adverse events, *n* (%)	14(4.7)	19(6.4)	0.727(0.371 to 1.423)	0.350[a]
-Cough, *n* (%)	14(4.7)	17(5.7)	0.813(0.408 to 1.618)	0.554[a]
-Hiccup, *n* (%)	0(0)	2(0.7)	NA	0.246[b]

RR, relative risk; CI, confidence interval; IQR, interquartile range; SpO2, saturation of peripheral oxygen; NA, not applicable;

[a]P value from the Chi-square test

[b]P value from Fisher's exact test

[c]P value from the Mann-Whitney U test

Additional analysis

Patients who did not adhere to the study protocol were excluded from the per-protocol analysis. The demographic and clinical characteristics and results are presented in Additional file 1 and Additional file 2, respectively, and were consistent with those obtained from the intention-to-treat analysis population.

The post-hoc logistic regression analysis are presented in Additional file 3. BMI, ASA classification, and STOP-Bang score were strongly associated with the primary

outcome. Notably, Regarding the nasal clip, the results remained largely unchanged before and after adjustment for these factors.

Discussion

The single-lumen nasal cannula is the most commonly used oxygen inhalation device. When the expiratory flow rate declines, supplemental oxygen through a nasal cannula quickly fills the nasopharyngeal cavity and displaces the remaining air, thus enabling the next inspiration to contain a higher concentration of oxygen. However, during respiration, oxygen continuously escapes through the mouth and the non-oxygen-inhaling nostril, limiting the ability of nasal cannulas to effectively increase oxygen inhalation. Several methods, including supraglottic jet oxygenation [12, 13], nasal masks [14], mask adaptors [19], and high-flow nasal cannulas [20] have been shown to be superior to nasal cannulas. However, the cost-effectiveness of these methods makes them unsuitable for the majority of patients. It is suggested that inspiratory muscle training may reduce the incidence of hypoxemia [21]. However, implementing this training for patients over a duration of 4 weeks is impractical in a fast-paced endoscopic center.

Our findings suggested that the combination of nasal clips and nasal cannulas was more effective at preventing hypoxemia compared with the use of nasal cannulas alone. Additionally, the nasal clip group had a lower lowest SpO_2 than the nasal cannula group. However, our results indicated that the effectiveness of nasal clips in increasing oxygen inhalation was limited. No significant differences were found for the duration of hypoxemia or the incidence of severe hypoxemia. In contrast, supraglottic jet oxygenation [12, 13] and high-flow nasal cannulas [20] have all been shown to have advantages in reducing severe hypoxemia. These differences may be attributed to the inherent limitation of nasal cannulas in enhancing the inhaled oxygen concentration. In our study, during instances of hypoxemia, it was often necessary to raise the oxygen flow rate from 2 to 6 L/min to achieve a higher inhaled oxygen concentration. Given the limited volume of the nasopharyngeal cavity [22], it becomes adequately filled after the expiratory flow rate declines during late expiration at an oxygen flow rate of 6 L/min.

Anesthetists had the discretion to adhere to our treatment protocol for hypoxemia based on the individual condition. Notably, all patients with subclinical respiratory depression had their jaws lifted, leading to the same results for the two secondary outcomes. However, not all hypoxemic patients required an increase in oxygen flow rates from 2 to 6 L/min, as a minority experienced timely restoration of respiratory efficiency. And no significant differences were found between the two groups in the measures used to increase oxygen saturation levels. In contrast, previous studies investigating high-flow nasal cannulas and nasal masks reported a reduced need for jaw lifting and higher oxygen flow rates [14, 20]. These discrepancies may be attributed to different strategies employed for managing hypoxemia.

During our study, we noticed that nasal cannulas made it less convenient to securely attach nasal clips to the nose, particularly for individuals with a flat nasal bridge or oily skin. To mitigate this, we found that wiping oil from the nasal ala effectively prevented the nasal clip from slipping. Despite these measures, we observed one case of severe hypoxemia caused by improper use of the nasal clip without timely detection. This misuse led to a blockage of oxygen flow to the nasopharyngeal cavity through the nasal passage, ultimately resulting in hypoxemia. Upon removal of the nasal clip, the oxygen saturation gradually improved. However, such issues can be overcome by trained medical workers. Besides that, we also encountered two cases of mild epistaxis after wearing nasal clips. In both instances, the nasal clips were promptly removed upon the initial sign of bleeding, and the bleeding was quickly controlled through the application of pressure. And this combination may be suitable for promotion in primary hospitals with limited resources and facilities, given its ease of adoption and potential economic viability, though its cost-effectiveness profile requires further verification.

This study has several limitations. First, we focused only on single-lumen nasal cannulas, limiting the applicability of our results to dual-lumen nasal cannulas that deliver oxygen through both nostrils simultaneously. Second, the use of nasal clips during preoxygenation before sedation allowed participants to potentially identify their assigned group, and the researchers could also observe this. This lack of blinding may have introduced bias into the results. Third, we excluded patients with severe pulmonary disease, a population that is more prone to hypoxemia, particularly within 5 min after sedation induction [23]. Therefore, our findings are primarily applicable to individuals with normal lung function. Fourth, we did not monitor respiratory rate and end-tidal carbon dioxide, which could potentially offer earlier detection of hypoventilation compared to SpO2 monitoring. Fifth, Despite using the STOP-Bang Questionnaire to assess patients for potential obstructive sleep apnea, we did not categorize the severity of obstructive apneas within our patient population Such distinction would be instrumental in clarifying the appropriate patient population for nasal clip use, given that the nasal clip obstructs the nasal passage. Additional research is required for different populations and dual-lumen nasal cannulas.

Conclusions

In conclusion, the combination of nasal clips and single-lumen nasal cannulas effectively decreases the incidence of hypoxemia in patients receiving gastrointestinal endoscopy with sedation, demonstrating a significant advantage over the use of nasal cannulas alone, with tolerable adverse events.

Abbreviations

RR	Relative risk
CI	Confidence interval
OR	Odds ratio
SpO2	Saturation of peripheral oxygen
IQR	Interquartile range
CONSORT	Consolidated standards of Reporting Trials
BMI	Body mass index
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
NA	Not applicable

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-024-02863-5.

Supplementary Material 1: Baseline characteristics for the per-protocol population

Supplementary Material 2: Outcomes for the per-protocol population

Supplementary Material 3: Univariate and Multivariate binary logistic regression analysis for hypoxemia

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Author contributions

Lu R and Xiang HF contributed equally to this study, they assisted with the study design and conduct, data interpretation, manuscript drafting and revision. Zhu MS, Cao Y, Shao XD and Chen LY assisted with the study conduct and data interpretation. Yu G and Tung TH assisted with data curation and analysis. Du WJ interpreted the data and made critical revisions related to important intellectual content of the manuscript. Cao JB and Wang MC contributed equally to this study, and they helped with the study conception and design, supervision, data interpretation and revision of the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of Taizhou Enze Medical Centre (Group) Enze Hospital, Taizhou, Zhejiang, China (approval no. K20220307) on 28 March 2022. All participants provided written informed consent before participation. The trial followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines and was registered before patient recruitment at the Chinese Clinical Trial Registry (registration no. ChiCTR2200065407; date of registration: November 4, 2022).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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