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Effects of anesthetic nasal masks on hypoxemia in overweight/obese patients undergoing gastroscopy: a randomized controlled trial

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Abstract

Background Overweight and obese patients are at a higher risk of hypoxemia during sedated gastroscopy due to impaired respiratory function. The aim of this study was to investigate whether an anesthetic nasal mask could have a positive outcome in preventing hypoxemia in such patients compared with a conventional nasal catheter.

Methods This prospective, randomized controlled trial enrolled 146 overweight/obese patients (BMI ≥ 25 kg/m^2) who underwent sedated gastroscopy from February 15, 2022, to December 31, 2022. Patients were randomly assigned (1:1) to receive oxygen via nasal masks or nasal cannulas using a computer-generated randomization sequence. The sample size was calculated based on an expected reduction in hypoxemia incidence from 40 to 15%, with a significance level of 0.05 and a power of 90%. Statisticians responsible for data analysis were blinded to group assignments. Both groups received standardized oxygen delivery with initial flow rates (5 L/min) to minimize procedural variability. The primary outcome was the incidence of hypoxemia ($SpO_2 \leq 90\%$). Secondary outcomes included the incidence of severe hypoxemia, rescue airway interventions, and adverse events.

Results Of the 146 patients, 73 were assigned to the nasal mask group and 73 to the nasal cannula group. The incidence of hypoxemia was significantly lower in the nasal mask group (13.7%) compared with the nasal cannula group (37.0%; absolute risk reduction [ARR] = 23.3%, 95% CI 9.7–36.9%%, $p = 0.002$; relative risk reduction [RRR] = 63.0%). In addition, the nasal mask group required fewer rescue airway interventions, such as jaw thrusts and noninvasive ventilation. No significant differences were observed in adverse events between the two groups.

Conclusions Nasal masks significantly reduce hypoxemia (with a 63% relative risk reduction) and the need for airway interventions during sedated gastroscopy in overweight/obese patients, without increasing adverse events. These findings support the use of nasal masks as an effective and safe airway management strategy for this patient population.

Clinical trial registration number ChiCTR2100053388

Keywords Gastroscopy, Hypoxemia, Nasal cannula, Nasal mask, Obesity, Overweight

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Introduction

Gastrointestinal endoscopy is a commonly performed medical procedure crucial for the early detection of digestive disorders. Advancements in medical technology have led to widespread use of sedation during gastroscopy, improving patient comfort and facilitating operational ease for endoscopists [1, 2].

Overweight or obesity affects 59% of adults and almost 33% of children in the European Region, according to the latest World Health Organization report on obesity in Europe. Overweight and obesity have become an epidemic in this region [3]. Many pathological changes are associated with overweight and obesity, including impaired respiratory function, reduced vital capacity, ventilation–perfusion mismatch, and increased oxygen consumption [4]. During sedated gastroscopy, these risks are further amplified by the lateral positioning required for the procedure, which exacerbates diaphragmatic elevation and abdominal pressure, limiting tidal volume and alveolar ventilation [5]. In addition, sedation-induced muscle relaxation predisposes obese patients to upper airway collapse, particularly in the oropharynx, where fat deposition narrows the airway lumen [6, 7]. The insertion of the gastroscope itself may mechanically obstruct the hypopharynx or trigger laryngospasm, further compromising oxygenation [7]. Previous studies have indicated that hypoxemia occurs in 17.4% of elderly patients and in a greater proportion (42.4%) of obese patients during such procedures [8, 9].

Conventional nasal cannulas have a maximum oxygen flow rate of 6 L/min, delivering an oxygen concentration of up to 45%. However, at flow rates exceeding 2 L/min, they can cause significant irritation and dryness to the nasal passages [10]. In patients under sedation, tongue retroversion may further limit oxygen delivery, and airway obstruction can substantially increase the risk of hypoxemia despite the use of nasal cannulas [11]. These limitations often render conventional nasal cannulas insufficient to meet the oxygen demands of deeply sedated patients or those with poor tolerance to hypoxia, particularly obese individuals who are at heightened risk of hypoxemia due to inadequate oxygen supply. Various methods, such as high-flow nasal cannulas, endoscopy face masks, nasopharyngeal airways, and bilevel-positive airway pressure, have been employed to mitigate hypoxemia during sedated gastroscopy [9, 12–14]. Despite the availability of various airway devices, their limitations—including complexity, patient intolerance, or interference with the procedure—necessitate the exploration of simpler, more effective options such as nasal masks.

The anesthetic nasal mask is specifically designed to accommodate the anatomical features of overweight and obese patients. It features two silicone nasal plugs that provide an effective seal within the nasal cavity and deliver a high concentration of oxygen, thereby maintaining adequate oxygenation during sedated gastroscopy. This design also allows for assisted and regulated ventilation without interrupting procedural continuity. The silicone material ensures both patient comfort and a secure seal, minimizing the risk of nasal injury.

In the present study, nasal masks were assessed for their effectiveness and safety in preventing hypoxemia during sedated gastroscopy in overweight/obese patients. Nasal masks provide continuous positive-pressure ventilation without interrupting gastroscopy, and positive-pressure ventilation strategies are effective in preventing and treating hypoxemia. We expected that nasal masks would effectively mitigate hypoxemia during sedated gastroscopy without disrupting the endoscopist's procedure, thereby enhancing both procedural efficiency and patient safety.

Materials and methods

Study design and patients

The research protocol was reviewed and approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University (Approval No. PJ2022-01-10, January 6, 2022). Prior to enrolling patients, the study was registered with the Chinese Clinical Trial Registry (ChiCTR2100053388, registration date: November 20, 2021). The study was conducted from February 15, 2022, to December 31, 2022, according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines. This prospective, randomized, controlled trial enrolled overweight/obese patients who underwent sedated gastroscopy. All participants provided written informed consent.

The inclusion criteria were as follows: male or female individuals classified according to the American Society of Anesthesiologists (ASA) Classification I–III, with a body mass index (BMI) ≥ 25 kg/m^2, who underwent sedated gastroscopy.

The exclusion criteria for participants were as follows: BMI ≥ 40 kg/m^2 (these patients are at significantly higher risk of severe hypoxemia and perioperative complications due to extreme obesity-related physiological challenges [15, 16]), baseline peripheral oxygen saturation < 95% (suboptimal pre-procedural oxygenation is strongly associated with intraoperative hypoxemia risk [12]), severe cardiopulmonary diseases, known allergies to anesthetics, acute pharyngitis, tonsillitis, nasal diseases (such as nasal polyps, epistaxis and rhinitis), myocardial infarction within the past 6 months, unstable angina, or procedures lasting more than 1 h.

Anesthesia management

Before gastroscopy, all the subjects underwent a minimum 8-h fasting period. Following the establishment of intravenous access, the subjects were positioned in the left lateral position for standardized monitoring (including SpO_2, blood pressure, heart rate, and electrocardiogram). Subsequently, sedation was administered, and gastroscopy was conducted. All study participants received sedation according to a standardized protocol to ensure uniformity and facilitate result comparability.

Prior to sedation, the subjects were instructed to take eight deep breaths of pure oxygen over a 1-min period. Following a 2-min interval after intravenous administration of 5 μg sufentanil, sedation was initiated with a 50 mg propofol bolus followed by continuous infusion at 5 mg/s. Subsequent titration of propofol in 20 mg increments was performed until loss of eyelash reflex was observed. The depth of sedation was assessed by means of the MOAA/S (Modified Observer Assessment of Alertness/Sedation) score, which ranges from 0 to 5. Repeat injections of propofol (0.5 mg/kg) were implemented as needed to facilitate a sustained MOAA/S score of ≤ 2. Fluids and ephedrine were administered for hypotension (mean arterial pressure < 65 mmHg), whereas atropine (0.5 mg) was administered if patients experienced bradycardia (heart rate < 50 beats per minute).

Randomization and blinding

In this study, the subjects were randomly assigned to use nasal mask oxygen or nasal cannula oxygen on the basis of a computer-generated random number. The nasal masks and nasal cannulas used in the clinical trial exhibited marked differences in appearance. Therefore, the anesthesiologists, endoscopists, patients, and data recorders were not blinded to the group assignments. However, the statisticians responsible for data analysis and experimental evaluation remained blinded to the group assignments.

Management of airways

Nasal masks (Jiangsu Nhwa Pharmaceutical Co., Ltd., China) are available in three different models, including small (model: AS-C-T), medium (model: AM-C-T) and large (model: AL-C-T) models. The appropriate nasal mask size was selected by the anesthesiologist based on the patient's nasal anatomy to ensure an optimal fit and minimal air leakage. In the nasal mask group, nasal masks were used for oxygen (Fig. 1a), which were selected by the anesthesiologist according to the patient's nasal cavity size. The nasal mask was connected to the anesthesia machine's breathing circuit, the initial oxygen flow rate was set to 5 L/min, and the mask was secured via a belt. The subjects in the nasal cannula group were given oxygen via a standard nasal cannula (Fig. 1b), and the initial oxygen flow rate was also 5 L/min.

In cases of hypoxemia during the procedure, the following interventions were performed sequentially: (i) increasing the oxygen flow rate to 10 L/min, (ii) jaw thrust, (iii) using a face mask for mechanical ventilation if hypoxemia did not improve, and (iv) considering intubation for mechanical ventilation if other measures failed.

Outcome measures

The incidence of hypoxemia was a primary outcome measure, defined as SpO_2 ≤ 90% for more than 5 s but less than 1 min.

The secondary outcome measures included the following:

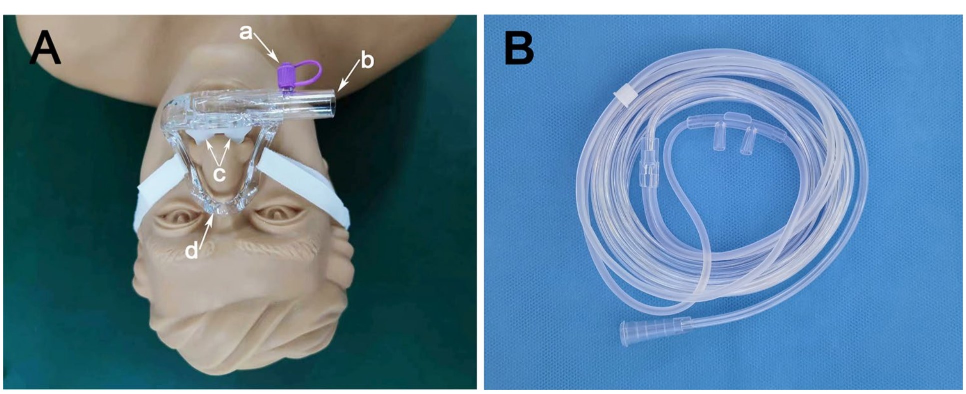

Fig. 1 Representative images of the anesthetic nasal mask and nasal cannula. **A** Anesthetic nasal mask. **a** End-expiratory carbon dioxide monitoring port, **b** connection ports for ventilator/anesthesia machine tubing, **c** silicone plug, and **d** fixed nasal frame. **B** Traditional nasal cannula

1. Other indicators of hypoxemia: incidence of severe hypoxemia ($SpO_2 \leq 90\%$ for 1 min or $SpO_2 \leq 75\%$ whenever) [17–19], minimum SpO_2.
2. Rescue airway management: increasing the flow of oxygen, jaw thrust, and mask-assisted ventilation
3. Adverse events: coughing, hiccups, and movements.
4. Complete satisfaction of the endoscopist and anesthesiologist: satisfaction was rated on a scale of 1–10, with a score of 9 or higher indicating complete satisfaction.

Sample size
PASS 21.0 software (NCS, LLC, Kaysville, Utah, USA) was used to determine the sample size. Data from previous studies suggest that approximately 40% of obese patients undergoing sedated gastroscopy with conventional nasal cannula oxygen experienced hypoxemia, and that the incidence of hypoxemia was reduced to approximately 15% when oxygen delivery was optimized [9, 12]. It was postulated that the use of nasal masks would reduce the incidence of hypoxemia from 40 to 15%. A sample size of 65 patients in each group was estimated using a significance level of 0.05 and a power of 0.9, in accordance with the requisite statistical standards. This number was increased to 146 patients (73 in each group) to allow for an anticipated dropout rate of 10%.

Statistical analysis
Data distribution was assessed via the Shapiro–Wilk test. Continuous variables are presented as the mean (standard deviation) for data that conform to a normal distribution or as the median (interquartile range [IQR]) for distributions that are skewed. Group differences were analyzed via appropriate statistical tests. Student's *t* test was used for normally distributed continuous variables, whereas the Mann–Whitney *U* test was used for skewed distributions. Categorical data are presented as numbers and percentages (%). To evaluate differences between groups, statistical tests were employed, including the chi-square test or Fisher's exact test, as appropriate.

We conducted a post hoc exploratory analysis to investigate the potential impact of clinical risk characteristics on the incidence of hypoxemia. These characteristics include BMI ≥ 30 kg/m^2 or < 30 kg/m^2, sex (male or female), Mallampati score ≥ 3 or < 3, the presence or absence of hypertension, the presence or absence of diabetes, and the presence or absence of coronary artery disease.

The absolute risk difference (ARD) and relative risk reduction (RRR) were calculated as follows. The package epiR (version: 2.0.74) was used to determine the 95% confidence interval (CI) for ARD.

ARD = incidence in nasal cannula group − incidence in nasal mask group;

RRR = (incidence in nasal cannula group − incidence in nasal mask group)/incidence in nasal cannula group.

The statistical analysis was conducted via R software (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria). *p* value of less than 0.05 was considered statistically significant.

Results
Among the 146 patients who underwent sedated gastroscopy, 73 were randomly assigned to the nasal mask group, and 73 were assigned to the nasal cannula group (Fig. 2).

Patient characteristics
The median age of the patients in the nasal cannula group was 49 years (interquartile range [IQR], 37–54). In addition, 69.9% of the patients in the nasal cannula group were male (Table 1). The median age of the nasal mask group was 51 years ([IQR], 39–56), and 71.2% of the patients were male (Table 1). The two groups showed similar demographic characteristics with respect to BMI, ASA classification, and Mallampati scores. No significant differences were observed in anesthetic dose, procedure duration, orientation recovery time, or eye-opening time between the two groups.

Primary outcome
In this study, the overall incidence of hypoxemia (defined as $SpO_2 \leq 90\%$ for more than 5 s but less than 1 min) was 25.3% (37/146). The incidence of hypoxemia was significantly lower in the nasal mask group (13.7%, 10/73) compared to the nasal cannula group (37.0%, 27/73), with an absolute risk reduction (ARD) of 23.3% (95% CI 9.7–36.9%; $p = 0.002$) and a relative risk reduction (RRR) of 63.0%. This suggests that nasal masks can be more suitable for sedated gastroscopy in overweight/obese patients.

Secondary outcomes
In the nasal cannula group, 11.0% (8/73) of patients experienced severe hypoxemia (defined as $SpO_2 \leq 90\%$ for 1 min or $SpO_2 \leq 75\%$ whenever) during sedated gastroscopy, whereas no cases of severe hypoxemia were observed in the group that received nasal mask oxygen ($p = 0.006$, Table 2). In addition, 9.6% (7/73) of patients in the cannula group experienced hypoxemia exceeding 60 s, whereas none were observed in the nasal mask group ($p = 0.013$, Table 2). Furthermore, 4.1% (3/73) of patients in the cannula group had $SpO_2 \leq 75\%$, with no

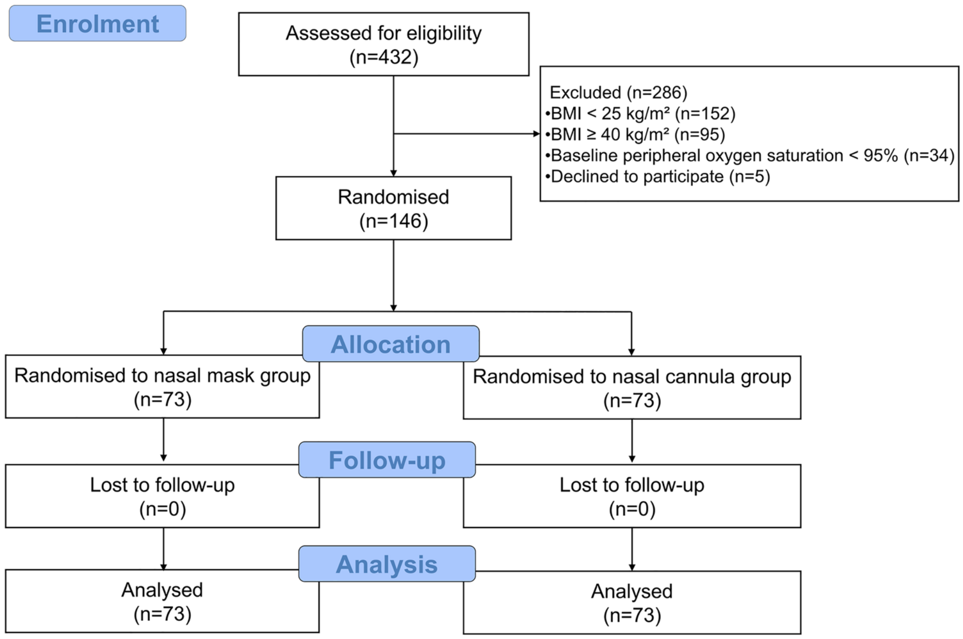

Fig. 2 CONSORT flow diagram

instances observed in the nasal mask group ($p=0.245$, Table 2). The lowest recorded SpO_2 was 99% ([IQR], 96–99) in the nasal mask group and 93% ([IQR], 87–97) in the nasal cannula group ($P<0.001$, Table 3).

The incidence of rescue airway management was significantly lower in the nasal mask group than in the nasal cannula group. There were no significant differences between the two groups in the incidence of coughing, hiccups, and body movements (Table 3), and no cases of severe complications were observed. The satisfaction levels of anesthesiologists and endoscopists were greater in the nasal mask group than in the nasal cannula group (95.8% vs. 76.7%, $p=0.002$; 93.2% vs. 75.3%, $p=0.005$).

Subgroup analysis

To gain further insight into the beneficial effect of nasal mask oxygen on the incidence of hypoxemia in the subgroup population, a post hoc exploratory analysis was conducted on the basis of identified risk factors for hypoxemia, such as BMI, sex, Mallampati score, hypertension, and diabetes (Fig. 3). Formal interaction tests indicated no significant heterogeneity in treatment effects across prespecified subgroups (all P for interaction >0.05), supporting the consistent benefit of nasal mask oxygenation regardless of BMI, sex, or Mallampati score. The intervention's positive effect on reducing hypoxemia incidence remained consistent across subgroups stratified by these variables. When the study population was divided according to the presence or absence of comorbid hypertension and diabetes, no significant advantage was observed in the use of nasal masks for those with comorbidities.

Discussion

Numerous studies have consistently linked overweight/obese individuals with a higher incidence of hypoxemia during sedated gastroscopy [12, 20, 21]. These individuals often exhibit physiological changes, such as reduced lung capacity, ventilation/perfusion mismatch, and increased oxygen consumption, and may suffer from conditions, including sleep apnea and upper airway obstruction [15, 22]. These factors significantly increase the likelihood of hypoxemia during sedated gastroscopy. Anesthetic agents can depress the respiratory center and impair respiratory muscle function [23], a sensitivity exacerbated in overweight and obese patients, further increasing the risk of hypoxia [24]. While respiratory depression may be transient, it can interrupt or necessitate the cessation of the gastroscopy procedure or lead to hypoxemia requiring immediate intervention [25].

Several studies have investigated strategies to prevent hypoxemia during sedated gastroscopy in overweight/

Table 1 Patient baseline characteristics

Characteristic	Nasal cannula group (73)	Nasal mask group (73)	*p* value
Age, years	49 (37–54)	51 (39–56)	0.112
Sex, *n* (%)			0.856
Male	51 (69.9)	52 (71.2)	
Female	22 (30.1)	21 (28.8)	
BMI, kg/m^2, *n* (%)			0.857
25–29.9	52 (71.2)	50 (68.5)	
30–39.9	21 (28.8)	23 (31.5)	
ASA classification, *n* (%)			0.812
1	11 (15.1)	12 (16.4)	
2	61 (83.5)	59 (80.9)	
3	1 (1.4)	2 (2.7)	
Mallampati score, *n* (%)			0.232
1	9 (12.3)	7 (9.6)	
2	26 (35.6)	36 (49.3)	
3	30 (41.1)	27 (37)	
4	8 (11.0)	3 (4.1)	
Medical history, *n* (%)			0.593
Hypertension	19 (26.0)	24 (32.9)	
Diabetes	5 (6.8)	6 (8.2)	
Coronary artery disease	3 (4.1)	1 (1.4)	
SpO_2 in ambient air before pre-oxygenation	98 (97–98)	98 (97–98)	0.942
Propofol, mg	140 (130–155)	140 (130–150)	0.810
Sufentanil, µg	5 (5–5)	5 (5–5)	1
Duration of procedure, min	5 (4–6)	5 (4–6)	0.442
Time to open eyes, min	1 (0–2)	0 (0–1)	0.211
Time of recovery of orientation force, min	2 (1–3)	2 (1–3)	0.455

The binary data are presented as numbers (%), and the continuous data are presented as medians (25th–75th percentiles)

BMI, body mass index; ASA, American Society of Anesthesiologists

Table 2 Outcomes in terms of peripheral desaturation events

	Nasal cannula group (73)	Nasal mask group (73)	ARD% (95% CI)	*p* value
Primary outcome				
Incidence of hypoxemia, *n* (%)	27 (37.0)	10 (13.7)	23.3 (9.7–36.9)	0.002
Secondary outcomes				
severe hypoxemia, *n* (%)	8 (11.0)	0	11.0 (3.7–20.2)	0.006
The duration of hypoxemia > 60 s, *n* (%)	7 (9.6)	0	9.6 (2.6–18.5)	0.013
$SpO_2 \leq 75\%$, *n* (%)	3 (4.1)	0	4.1 (− 1.6 to 11.4)	0.245
Lowest SpO_2, median (IQR), %	93 (87–97)	99 (96–99)		< 0.001

Data are presented as number (%) or median (25th–75th percentile)

Hypoxemia: $SpO_2 \leq 90\%$ for more than 5 s but less than 1 min

Severe hypoxemia: $SpO_2 \leq 90\%$ for 1 min or $SpO_2 \leq 75\%$ whenever

ARD, absolute risk difference; CI, confidence interval

obese patients. Nay et al. [9] and Riccio et al. [26] reported that increasing the oxygen flow through nasal cannulas effectively reduces hypoxemia occurrence during sedated gastroscopy in obese patients. However, potential limitations need to be considered. Sedation can induce respiratory depression or even apnea in

Table 3 Rescue airway management, adverse events and satisfaction

	Nasal cannula group (73)	Nasal mask group (73)	*p* value
Rescue airway management, *n* (%)			
Increase the flow of oxygen	23 (31.5)	9 (12.3)	0.009
Jaw thrust	20 (27.4)	8 (11.0)	0.021
Mask-assisted ventilation	15 (20.5)	1 (1.4)	< 0.001
Adverse events, *n* (%)			
Coughing	4 (5.5)	6 (8.2)	0.743
Hiccups	3 (4.1)	2 (2.7)	1.000
Body movement	4 (5.5)	3 (4.1)	1.000
Complete satisfaction, *n* (%)			
The satisfaction of endoscopist	55 (75.3)	68 (93.2)	0.006
The satisfaction of anesthesiologist	56 (76.7)	70 (95.9)	0.002

Data are presented as numbers (%) or medians (25th–75th percentiles)

overweight/obese patients, and simply increasing oxygen flow may not fully alleviate hypoxemia. Moreover, high-flow oxygen delivery via nasal cannulas can lead to nasal mucosal drying [27, 28], and its high cost may limit its widespread use, given the millions of gastroscopies performed annually worldwide. High-flow oxygen also makes end-tidal CO_2 monitoring difficult [29, 30]. The use of endoscopic face masks can increase oxygen concentrations in the nasal and oral cavities of spontaneously breathing patients and facilitate assisted or controlled ventilation. Despite these advantages, face mask ventilation may present drawbacks, such as feelings of claustrophobia, potential skin irritation, and the risk of rebreathing carbon dioxide [31–33]. Bilevel positive airway pressure (BiPAP) devices can be effective but are bulky, complex to use, and may interfere with the endoscopist's workflow during procedures.

Prior to conducting this study, we reviewed existing research on nasal masks. Previous research conducted by Chen DX et al. [18] compared the effectiveness of nasal masks with traditional nasal cannulas for gastroscopy under intravenous anesthesia. However, there are notable differences between their study and ours. First, the nasal mask used by Chen DX et al. was an infant-sized mask originally designed for pediatric use, which may resulted in inadequate sealing, reduced patient comfort and limited adaptability to diverse nasal anatomies. In contrast, the nasal mask used in this study was designed on the basis of adult nasal anatomy to ensure effective ventilation sealing. In addition, our nasal mask is available in three sizes (small, medium, and large), catering to the diverse nasal anatomies of adults. Second, Chen DX et al. included a general adult population without explicit focus on obesity. Their results, while informative, may not fully address the unique challenges of managing hypoxemia in overweight/obese patients. This study specifically targeted overweight/obese patients (BMI ≥ 25 kg/m^2), a population at significantly elevated risk of hypoxemia during sedation. The inclusion of obese patients strengthens the generalizability of nasal masks for complex airway management scenarios, a population often excluded or underrepresented in prior studies. Drews et al. [16] also proposed the use of a nasal positive airway pressure mask to prevent hypoxemia in overweight patients underwent sedated gastroscopy. Compared to the nasal manual positive airway pressure mask described by Drews et al., the nasal mask used in this study offers several distinct advantages: it is simpler, more compact, lighter, and easier to use. In addition, it can be connected to a ventilator or anesthesia machine for mechanical ventilation. A notable advantage of the nasal mask used in this study is its capacity to monitor respiratory end-tidal CO_2 concentrations. This feature is particularly crucial for overweight/obese patients under sedation. Monitoring end-tidal carbon dioxide enables early detection of respiratory depression and carbon dioxide retention, facilitating timely intervention. These findings set this study apart from others that have assessed nasal masks in similar contexts.

Nevertheless, the findings of this study must be considered within the context of its inherent limitations. First, morbidly obese patients were excluded, because such patients are at high risk of developing difficulties with mask ventilation and intubation, and because the severe hypoxemia may threaten patient safety. However, the results of the exploratory analysis found that nasal masks reduced the incidence of hypoxemia in patients with a BMI ≥ 30 kg/m^2, and similar findings may be present in morbidly obese patients. Second, we did not evaluate its applicability in colonoscopy procedures. Third, the study was not conducted under blinded conditions because of the unavoidable identification of the oxygen supply device. Nevertheless, to mitigate any potential information bias, independent researchers who were blinded to the group assignments undertook the evaluation and analysis of the postoperative endpoints. Finally, the BIS is not used to monitor the depth of sedation due to endoscopy center limitations. Future studies with larger sample sizes and predefined hypotheses should confirm these exploratory results.

To summarize, the results of this study indicate that nasal masks effectively employed during sedated gastroscopy in overweight and obese patients, offering significant advantages over traditional nasal cannulas. Given the statistically significant reduction in hypoxemia

Patient subgroups	Nasal cannula group(n=73)	Nasal mask group(n=73)	ARD(95%)	P value	P for interaction
BMI					**0.443**
< 30 kg/m^2	19/52(36.5)	8/50(16.0)	20.5(4.0 to 37.1)	0.019	
≥ 30 kg/m^2	8/21(38.1)	2/23(8.7)	29.4(5.7 to 53.2)	0.031	
Sex					**0.283**
Male	17/51(33.3)	8/52(15.4)	18.0(1.7 to 34.2)	0.034	
Female	10/22(45.5)	2/21(9.5)	35.9(11.6 to 60.2)	0.009	
Mallampati					**0.816**
≤ 2	12/35(34.3)	5/43(11.6)	22.7(4.2 to 41.1)	0.016	
≥ 3	15/38(39.5)	5/30(16.7)	22.8(2.3 to 43.3)	0.040	
Hypertension					**0.100**
Yes	5/19(26.3)	5/24(20.8)	5.5(−20.1 to 31.1)	0.953	
No	22/54(40.7)	5/49(10.2)	30.5(14.9 to 46.1)	<0.001	
Diabetes					**0.382**
Yes	2/5(40.0)	2/6(33.3)	6.7(−50.5 to 63.8)	1.000	
No	25/68(36.8)	8/67(11.9)	24.8(11 to 38.7)	<0.001	

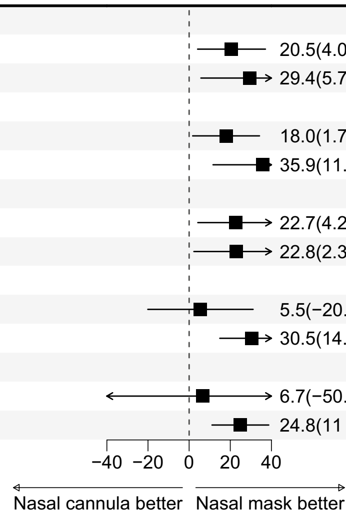

Fig. 3 Forest plot showing the absolute risk difference in the occurrence of hypoxemia across patient subgroups

incidence and the decreased need for rescue airway interventions, our findings suggest that nasal masks could be incorporated into anesthesia and endoscopy guidelines for overweight/obese patients undergoing sedated gastroscopy. Nevertheless, additional clinical studies are necessary to substantiate these findings and evaluate the suitability and efficacy of nasal masks for other medical procedures.

Conclusion

The use of nasal masks for oxygen supply reduces the incidence of hypoxemia in overweight/obese patients undergoing sedated gastroscopy.

Acknowledgements
Not applicable.

Author contributions
Huan Liu and Peipei Guo wrote the manuscript; Huan Liu and Lijian Chen were responsible for the statistics of the data. Huisheng Wu and Xuesheng Liu were the designers of the study. All authors reviewed and approved the final manuscript.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was in accordance with Declaration of Helsinki. The study was approved by the ethics committee of the First Affiliated Hospital of Anhui Medical University. Informed consent was obtained from all patients.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Radaelli F, Meucci G, Sgroi G, Minoli G. Italian Association of Hospital G: Technical performance of colonoscopy: the key role of sedation/analgesia and other quality indicators. Am J Gastroenterol. 2008;103(5):1122–30.
2. Cohen LB, Wecsler JS, Gaetano JN, Benson AA, Miller KM, Durkalski V, Aisenberg J. Endoscopic sedation in the United States: results from a nationwide survey. Am J Gastroenterol. 2006;101(5):967–74.
3. Boutari C, Mantzoros CS. A 2022 update on the epidemiology of obesity and a call to action: as its twin COVID-19 pandemic appears to be receding, the obesity and dysmetabolism pandemic continues to rage on. Metabolism. 2022;133: 155217.
4. Wang C, Wang Y, Zeng W, Shang S. The influencing of obesity on lung ventilation function among middle-aged and elderly people. Sci Rep. 2024;14(1):31954.
5. Katz S, Arish N, Rokach A, Zaltzman Y, Marcus EL. The effect of body position on pulmonary function: a systematic review. BMC Pulm Med. 2018;18(1):159.
6. Zhang H, Zhang M, Hao L, Li Q, Li Q, Yang J, Xie Y. Comparison of the effects of ciprofol and propofol on postoperative nausea and vomiting

in patients undergoing outpatient hysteroscopy. Drug Des Dev Ther. 2024;18:5701–7.
7. Amornyotin S. Sedation-related complications in gastrointestinal endoscopy. World J Gastrointest Endosc. 2013;5(11):527–33.
8. Liu F, Cheng X, Wang Y, Li K, Peng T, Fang N, Pasunooti KK, Jun S, Yang X, Wu J. Effect of remimazolam tosilate on the incidence of hypoxemia in elderly patients undergoing gastrointestinal endoscopy: a bi-center, prospective, randomized controlled study. Front Pharmacol. 2023;14:1131391.
9. Nay MA, Fromont L, Eugene A, Marcueyz JL, Mfam WS, Baert O, Remerand F, Ravry C, Auvet A, Boulain T. 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(1):133–42.
10. Mukherjee D, Mukherjee R. High-flow nasal cannula oxygen therapy in the management of respiratory failure: a review. Cureus. 2023;15(12): e50738.
11. Lee S, Choi JW, Chung IS, Kim TJ, Sim WS, Park S, Ahn HJ. Comparison of high-flow nasal cannula and conventional nasal cannula during deep sedation for endoscopic submucosal dissection: a randomized controlled trial. J Anesth. 2024;38(5):591–9.
12. Wang S, Shen N, Wang Y, Cheng N, Li L, Pan S, Aisan T, Hei Z, Luo G, Chen C. Bilevel positive airway pressure for gastroscopy with sedation in patients at risk of hypoxemia: a prospective randomized controlled study. J Clin Anesth. 2023;85: 111042.
13. Cai G, Huang Z, Zou T, He M, Wang S, Huang P, Yu B. Clinical application of a novel endoscopic mask: a randomized controlled trial in aged patients undergoing painless gastroscopy. Int J Med Sci. 2017;14(2):167–72.
14. Qin Y, Li LZ, Zhang XQ, Wei Y, Wang YL, Wei HF, Wang XR, Yu WF, Su DS. Supraglottic jet oxygenation and ventilation enhances oxygenation during upper gastrointestinal endoscopy in patients sedated with propofol: a randomized multicentre clinical trial. Br J Anaesth. 2017;119(1):158–66.
15. Brondeel KC, Lakatta AC, Torres GB, Hurley JJ, Kunik IL, Haney KF, Cornett EM, Kaye AD. Physiologic and pharmacologic considerations in morbid obesity and bariatric anesthesia. Saudi J Anaesth. 2022;16(3):306–13.
16. Drews J, Harder J, Kaiser H, Soenarjo M, Spahlinger D, Wohlmuth P, Wirtz S, Eberhardt R, Bornitz F, Bunde T, et al. Impact of a simple non-invasive nasal mask device on intraprocedural hypoxemia in overweight individuals undergoing upper gastrointestinal endoscopy with sedation provided by a non-anesthesiologist provider. Clin Endosc. 2024;57(2):196–202.
17. Getu MA, Wang P, Addissie A, Seife E, Chen C, Kantelhardt EJ. The effect of cognitive behavioural therapy integrated with activity pacing on cancer-related fatigue, depression and quality of life among patients with breast cancer undergoing chemotherapy in Ethiopia: a randomised clinical trial. Int J Cancer. 2023;152(12):2541–53.
18. Chen DX, Yang H, Wu XP, Niu W, Ding L, Zeng HL, Li Q. Comparison of a nasal mask and traditional nasal cannula during intravenous anesthesia for gastroscopy procedures: a randomized controlled trial. Anesth Analg. 2022;134(3):615–23.
19. Zha B, Wu Z, Xie P, Xiong H, Xu L, Wei H. Supraglottic jet oxygenation and ventilation reduces desaturation during bronchoscopy under moderate to deep sedation with propofol and remifentanil: a randomised controlled clinical trial. Eur J Anaesthesiol. 2021;38(3):294–301.
20. Zheng L, Wang Y, Ma Q, Liang W, Zhang X, Ren Z, Qin W, Meng F, Li Y, Fan G, et al. Efficacy and safety of a subanesthetic dose of esketamine combined with propofol in patients with obesity undergoing painless gastroscopy: a prospective, double-blind, randomized controlled trial. Drug Des Devel Ther. 2023;17:1347–56.
21. Azeredo LM, Souza LC, Guimarães BLS, Puga FP, Behrens N, Lugon JR. Inspiratory muscle training as adjuvant therapy in obstructive sleep apnea: a randomized controlled trial. Braz J Med Biol Res Rev brasileira de pesquisas medicas e biologicas. 2022;55:e12331.
22. Charoensittisup P, Udomittipong K, Mahoran K, Palamit A. Longitudinal effects of obesity on pulmonary function in obese children and adolescents. Pediatric Res. 2024;2024:1.
23. Jansen SC, van Lemmen M, Olofsen E, Moss L, Pergolizzi JV Jr, Miller T, Colucci RD, van Velzen M, Kremer P, Dahan A, et al. Reversal of propofol-induced depression of the hypoxic ventilatory response by BK-channel blocker ENA-001: a randomized controlled trial. Anesthesiology. 2024;140(6):1076–87.
24. Saraswat V. Effects of anaesthesia techniques and drugs on pulmonary function. Indian J Anaesth. 2015;59(9):557–64.
25. Hu B, Jiang K, Shi W, Xiao S, Zhang S, Zhang Y, Zhou Y, Tan C, Tan S, Zou X. Effect of remimazolam tosilate on respiratory depression in elderly patients undergoing gastroscopy: a multicentered, prospective, and randomized study. Drug Des Dev Ther. 2022;16:4151–9.
26. Riccio CA, Sarmiento S, Minhajuddin A, Nasir D, Fox AA. High-flow versus standard nasal cannula in morbidly obese patients during colonoscopy: a prospective, randomized clinical trial. J Clin Anesth. 2019;54:19–24.
27. Nishimura M. High-flow nasal cannula oxygen therapy in adults: physiological benefits, indication, clinical benefits, and adverse effects. Respir Care. 2016;61(4):529–41.
28. El-Farghali OG. High-flow nasal cannula in neonates. Respir Care. 2017;62(5):641–2.
29. Gómez-Ríos M, Sastre JA, Onrubia-Fuertes X, López T, Abad-Gurumeta A, Casans-Francés R, Gómez-Ríos D, Garzón JC, Martínez-Pons V, Casalderrey-Rivas M, et al. Spanish Society of Anesthesiology, Reanimation and Pain Therapy (SEDAR), Spanish Society of Emergency and Emergency Medicine (SEMES) and Spanish Society of Otolaryngology, Head and Neck Surgery (SEORL-CCC) Guideline for difficult airway management. Part I. Rev espanola anestesiologia reanimacion. 2024;71(3):171–206.
30. Gómez-Ríos M, Sastre JA, Onrubia-Fuertes X, López T, Abad-Gurumeta A, Casans-Francés R, Gómez-Ríos D, Garzón JC, Martínez-Pons V, Casalderrey-Rivas M, et al. Spanish Society of Anesthesiology, Reanimation and Pain Therapy (SEDAR), Spanish Society of Emergency and Emergency Medicine (SEMES) and Spanish Society of Otolaryngology, Head and Neck Surgery (SEORL-CCC) Guideline for difficult airway management. Part II. Rev espanola anestesiologia reanimacion. 2024;71(3):207–47.
31. Spinazzola G, Ferrone G, Costa R, Piastra M, Maresca G, Rossi M, Antonelli M, Conti G. Comparative evaluation of three total full-face masks for delivering Non-Invasive Positive Pressure Ventilation (NPPV): a bench study. BMC Pulm Med. 2023;23(1):189.
32. Alqahtani JS, Worsley P, Voegeli D. Effect of humidified noninvasive ventilation on the development of facial skin breakdown. Respir Care. 2018;63(9):1102–10.
33. Acuti Martellucci C, Flacco ME, Martellucci M, Violante FS, Manzoli L. Inhaled $CO_{(2)}$ concentration while wearing face masks: a pilot study using capnography. Environ Health Insights. 2022;16:11786302221123572.

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