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ORIGINAL CLINICAL RESEARCH REPORT

Comparison of a Nasal Mask and Traditional Nasal Cannula During Intravenous Anesthesia for Gastroscopy Procedures: A Randomized Controlled Trial

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BACKGROUND: Hypoxemia can occur during gastroscopy under intravenous anesthesia. The aim of this randomized controlled trial was to evaluate whether oxygenation using a nasal mask can reduce the incidence of hypoxemia during gastroscopy under intravenous anesthesia compared with a traditional nasal cannula.

METHODS: A total of 574 patients scheduled for gastroscopy under intravenous anesthesia were enrolled and randomly assigned to receive either a nasal mask or a traditional nasal cannula for oxygenation. The primary outcome was the incidence of hypoxemia. The secondary outcomes included the incidence of severe hypoxemia, duration of hypoxemia, minimum oxygen saturation, the proportion of emergency airway management, length of procedure, recovery time, and the satisfaction of the anesthetist and gastroenterologists as well as other adverse events (including cough, hiccups, nausea and vomiting, reflux, aspiration, and laryngospasm).

RESULTS: A total of 565 patients were included in the analysis: 282 patients in the nasal cannula group and 283 patients in the nasal mask group. The incidence of hypoxemia was lower in the nasal mask group (18.0%) than in the nasal cannula group (27.7%; relative risk [RR] = 0.65; 95% confidence interval [CI], 0.48–0.89; $P = .006$), and the hypoxemia lasted a median of 18.0 seconds (interquartile range, 10.0–38.8) in the nasal mask group and 32.5 seconds (20.0–53.5) in the nasal cannula group (median difference –14.50; 95% CI, –22.82 to –1.34; $P = .047$). The proportion of patients requiring emergency airway management was significantly lower in the nasal mask group (8.8%) than in the nasal cannula group (19.1%; RR, 0.46; 95% CI, 0.30–0.73; $P < .001$). No difference was found in the overall incidence of other adverse events between the 2 groups (nasal mask 20.8%; nasal cannula 17.0%; RR, 1.23; 95% CI, 0.87–1.73; $P = .25$). Satisfaction was higher with the nasal mask than with the nasal cannula from the perspective of anesthetists (96.1% for nasal mask versus 84.4% for nasal cannula; RR, 1.14; 95% CI, 1.08–1.20; $P < .001$) and gastroenterologists (95.4% for mask versus 81.9% for cannula; RR, 1.17; 95% CI, 1.10–1.24; $P < .001$). There were no significant differences in the incidence of severe hypoxemia, minimum oxygen saturation, length of procedure, or recovery time between the 2 groups.

CONCLUSIONS: Nasal mask oxygenation reduced the incidence of hypoxemia during anesthesia for gastroscopy under intravenous anesthesia. (Anesth Analg 2022;134:615–23)

KEY POINTS

- **Question:** Does nasal mask oxygenation reduce the risk of hypoxemia during anesthesia for gastroscopy?
- **Findings:** In a randomized controlled trial that included 565 adult patients undergoing intravenous anesthesia for gastroscopy, we found that nasal mask oxygenation was associated with a significantly lower incidence of hypoxemia compared with traditional nasal cannula oxygenation (18.0% vs 27.7%).
- **Meaning:** Nasal mask oxygenation can be used in patients undergoing intravenous anesthesia for gastroscopy for whom it can significantly reduce the incidence of hypoxemia.

GLOSSARY

ASA = American Society of Anesthesiologists; **BMI** = body mass index; **CI** = confidence interval; **CONSORT** = Consolidated Standards of Reporting Trials; **HFNC** = high-flow nasal catheter; **IQR** = interquartile range; **OAAS** = Observer's Assessment of Alertness/Sedation Scale; **RR** = relative risk; **Spo_2** = pulse oxygen saturation

Each year, > 6 million esophagogastroduodenoscopy procedures are performed in the United States alone,[1] and >53% of endoscopies are now performed under intravenous anesthesia.[2] Hypoxemia often occurs during gastroscopy under intravenous anesthesia.[3–5] The current standard of care for most patients receiving intravenous anesthesia for gastroscopy is to administer supplementary oxygen via a standard nasal cannula, but hypoxemia still occurs in >40% of the patients.[6]

Several methods have been introduced to reduce the incidence of hypoxemia during gastroscopy. Previously, studies with small samples reported that high-flow nasal cannula (HFNC) oxygenation and the use of a nasopharyngeal catheter could reduce the incidence of hypoxemia during anesthesia for gastroscopy.[5–7] However, those methods require special supplemental oxygen devices or oxygen delivery systems or they induce adverse events such as nasopharyngeal bleeding.[6,7] Therefore, it is critical to find an appropriate method to prevent hypoxemia with fewer side effects during gastroscopy.

Randomized controlled trials have shown that continuous positive airway pressure through a nasal mask leads to higher effective tidal volume than a full-facemask during the induction of general anesthesia.[8] However, we are unaware of studies evaluating nasal mask oxygenation in patients during anesthesia for gastroscopy.

We conducted this randomized trial to evaluate the efficacy of nasal mask oxygen versus standard nasal cannula during gastroscopy. Specifically, we tested the hypothesis that nasal mask oxygen would result in a lower occurrence of hypoxemia during gastroscopy than a standard nasal cannula. The primary outcome was the occurrence of hypoxemia defined as an occurrence of Spo_2 <90%.

METHODS

Study Design and Patients

This study was approved by the ethics committee of the West China Hospital of Sichuan University, China, on December 29, 2018 (approval no. 2018-519). The study was registered at the Chinese Clinical Trial Registry before patient enrollment (ChiCTR 1900020691, principal investigator: Qian Li, date of registration: January 13, 2019) before patient enrollment, and it followed the guidelines of the Consolidated Standards of Reporting Trials guidelines. Written informed consent was obtained from all participants.

The inclusion criteria were: patients were 18 years of age or older, with American Society of Anesthesiologists (ASA) physical status I–III, and patients received intravenous anesthesia for gastroscopy. Exclusion criteria were: history of myocardial infarction and unstable angina pectoris within the past 6 months; history of severe arrhythmia, acute pharyngitis, and tonsillitis; pneumonia or pulse oxygen saturation (Spo_2) <90% without oxygen inhalation; severe obstructive sleep apnea syndrome; allergy to propofol, eggs, soybean, or albumin; lack of cooperation or motivation; pregnancy or lactation; and participation in other clinical studies within the previous 3 months.

Randomization and Blinding

The participants were randomly assigned to receive oxygen supply through either a nasal mask or a nasal cannula, according to a computer-generated allocation list (simple randomization) in a 1:1 ratio using the software SPSS (version 23.0, IBM). Since both groups of patients could be identified directly from the device used for supplemental oxygen, this study was not blinded to the anesthetists, patients, or data recorders. The postoperative outcome assessment and statistical analysis were performed by independent researchers who were blinded to group assignment.

Anesthesia Management

The only difference between the 2 groups was the method used for supplementing oxygen. All patients fasted for 8 hours before the gastroscopy. After admission to the examination room, standardized monitoring was performed, including heart rate, blood pressure, and Spo_2. After establishment of intravenous access, the patient was placed in a lateral position for gastrointestinal endoscopy. After adequate preoxygenation, anesthesia was induced using an intravenous injection of propofol (1–1.5 mg/kg), sufentanil (5–10 μg), and midazolam

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(0.01–0.02 mg/kg).[9,10] The gastroscopic examination began after disappearance of the palpebral reflex. If the heart rate stayed >100 beats/min or increased by >20%, or if physical movement or cough occurred, additional propofol (0.2–0.4 mg/kg) was administered until the gastroscope entered smoothly. During the gastroscopy, 10- to 30-mg propofol was administered as needed to maintain a Ramsay score of 5 or 6, corresponding to a sluggish or no response to a glabellar tap or loud auditory stimulus.[10]

Airway Management

In the nasal mask group, we did not use a traditional nasal mask because a disposable nasal mask oxygenation circuit at our hospital costs $60 compared with $6 for a nasal cannula. Based on the previous work in which an infant-size transparent anatomical facemask costing only $6 was used as a nasal oxygenation device to achieve effective ventilation,[11] we adopted an infant-sized transparent anatomical facemask as the nasal oxygenation device. We provided anesthetists 3 sizes of infant masks (6.5 × 6.5 cm, 8 × 6.7 cm, and 9.5 × 8 cm; Chongren Medical Instruments). The criterion for a properly sized mask was that it covered the nose area. The size of the infant mask was selected by the anesthetists after assessing the size of the patient's nose. As a result, all anesthetists selected the infant mask with the size of 8 × 6.7 cm, which was secured in place using a head strap (Figure 1A). The expiratory limb of the nasal mask was connected to a 2-L reservoir bag, which was connected to the oxygen, and the initial oxygen flow was 4 L/min.[6]

In the nasal cannula group, all patients received supplemental oxygen by nasal cannula (2.5 m; Hongxiang Maoyike) (Figure 1B) at an initial oxygen flow of 4 L/min. The patients were instructed to breathe through the nasal cannula or nasal mask for 1 to 2 minutes before anesthesia. If the Spo_2 dropped below 90% during the procedure, the treatment protocol in Figure 2 was implemented.

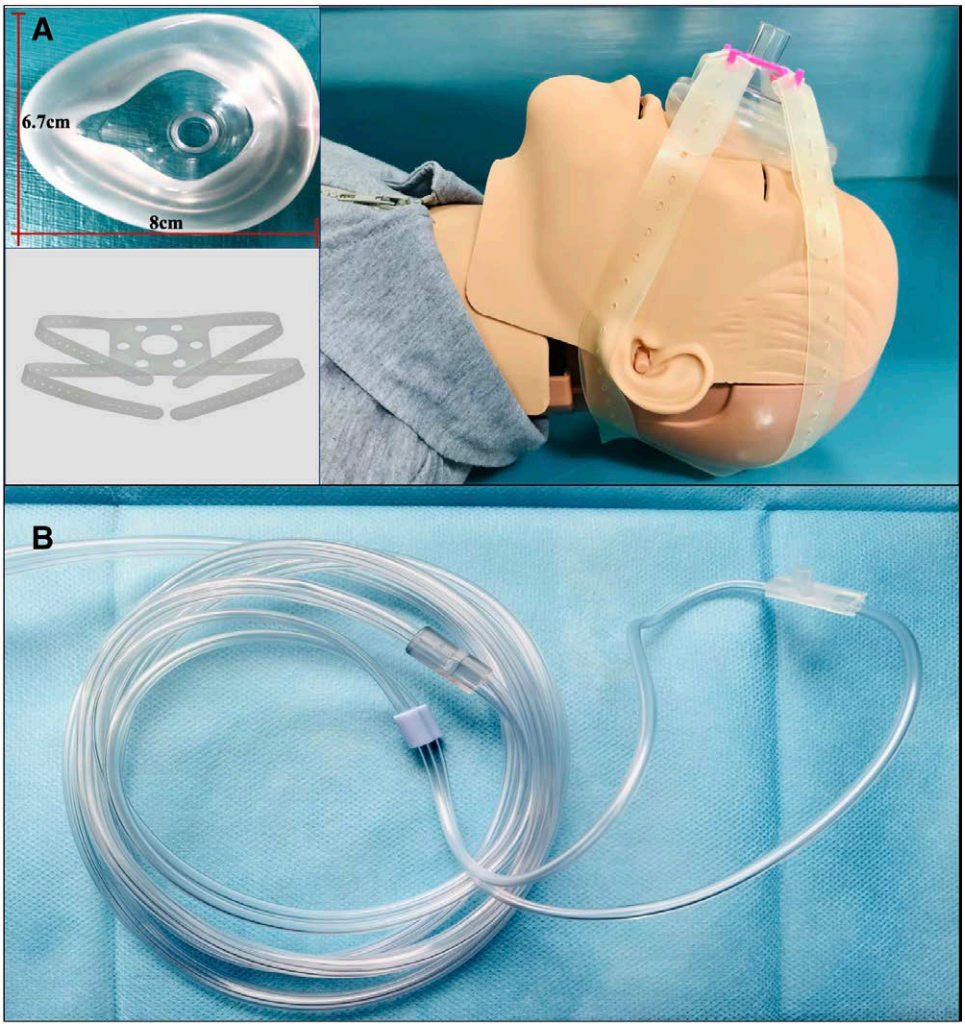

Figure 1. A representative image of the nasal mask and nasal cannula. A, Nasal mask (Chongren Medical Instruments). B, Nasal cannula of 2.5 m (Hongxiang Maoyike).

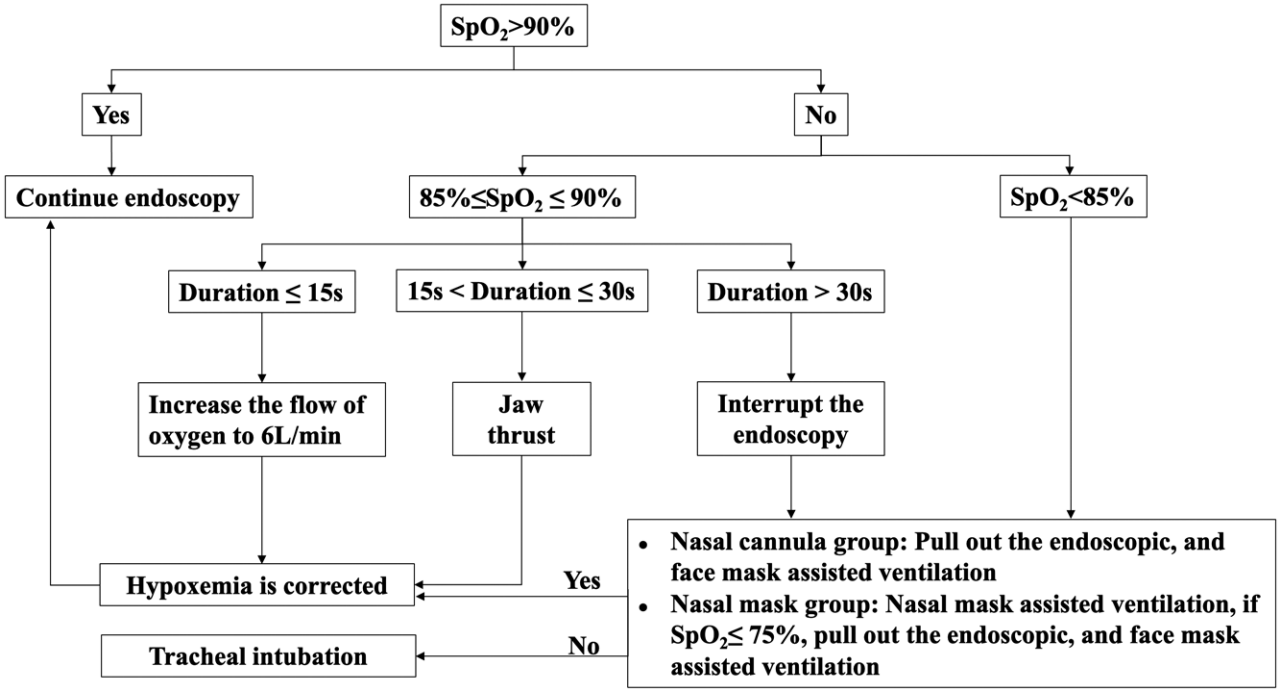

Figure 2. Flowchart of the hypoxemia management protocol applied in this study. Spo_2 indicates pulse oxygen saturation.

Study Outcomes

The primary outcome was the occurrence of hypoxemia, defined as any measurement/occurrence of Spo_2 ≤90% during the procedure.

Secondary outcomes included:

1. Occurrence of severe hypoxemia, defined as Spo_2 ≤75% or Spo_2 ≤90% for 60 consecutive seconds or longer during the procedure.[12]
2. Duration of hypoxemia (in seconds) and minimum Spo_2.
3. The proportion of patients requiring emergency airway management, defined as hypoxemia that could not be corrected by increasing the oxygen flow, but rather needed the jaw-thrust maneuver or interruption of the endoscopic operation for mask-assisted ventilation, or emergency tracheal intubation.
4. Occurrence of "other adverse events," a composite outcome including cough, hiccups, nausea and vomiting, reflux, aspiration, and laryngospasm. Patients were classified as experiencing any of these adverse events or none of them.
5. Length of procedure (in minutes), defined as the time from endoscope insertion into the oral cavity until its removal.
6. Recovery time (in minutes), which was defined as the time from the end of the procedure until a score of 5, was achieved on an Observer's Assessment of Alertness/Sedation Scale (OAAS), which indicated rapid response to a normal voice.[3]
7. Satisfaction about the procedure from the perspectives of anesthetists and gastroenterologists, evaluated on a 100-point scale, with complete satisfaction defined as ≥90 points.

Crisis Event Management

In the case of laryngospasm, an additional dose of 30- to 50-mg propofol was given as required, and the oxygen flow was increased. If necessary, the gastroenterologists were instructed to withdraw the endoscope, and the anesthetists applied positive pressure ventilation via the mask. If the patient could not ventilate through the mask, intravenous succinylcholine (50 mg) was given, and tracheal intubation was performed.

In case of regurgitation and aspiration, the gastroenterologists were asked to withdraw the endoscope and immediately suction the oropharynx. Meanwhile, the patient was placed in the Trendelenburg position, expeditiously intubated and mechanically ventilated as necessary, and fiberoptic bronchoscopy was performed to remove aspirated stomach contents from the trachea.

In the event of circulation abnormalities, several procedures were undertaken. In the case of heart rate <50 beats/min, an intravenous injection of atropine (0.3–0.5 mg) was administered. If the heart rate dropped when blood pressure also decreased (<90/60 mm Hg or a mean arterial pressure 20% lower than at baseline), an intravenous injection of ephedrine (6 mg) was administered and repeated as needed. If the heart rate was normal or above the normal range but with

low blood pressure (<90/60 mm Hg or a mean arterial pressure 20% lower than at baseline), an injection of m-hydroxylamine (0.1–0.2 mg) was administered and repeated as needed.

Statistical Analysis

The distribution of continuous variables was examined for normality. Data showing normal distribution were presented as mean (standard deviation), and data showing a skewed distribution were presented as median (interquartile range [IQR]). Intergroup differences were assessed for significance using a Student *t* test or Mann-Whitney *U* test, as appropriate. Difference in means or median difference and 95% confidence intervals (CIs) were presented depending on the normality of data distribution. Intergroup differences in the duration of hypoxemia, minimum Spo_2, operation time, and recovery time were assessed using the Mann-Whitney *U* test and by calculating the Hodges–Lehman median difference with 95% CI. Categorical data were expressed as numbers and percentages and were compared using a χ^2 test or Fisher exact test, as appropriate. The effects of nasal mask on incidences of hypoxemia, severe hypoxemia, emergency airway management, and other adverse events were presented as relative risk (RR) and 95% CI, as was satisfaction about the procedure from the perspectives of anesthetists and gastroenterologists. Intergroup differences in baseline characteristics were compared using the absolute standardized difference, and differences >1.96 sqrt[(1/N1) + (1/N2)] were considered imbalanced.[13] And in this study, absolute standardized differences >16.5% were considered imbalanced.

We assessed treatment effect heterogeneity by testing whether the treatment effect differed between levels of specified baseline variables, including age, ASA physical status, and body mass index (BMI). For this, we used logistic regression and assessment of the treatment-by-covariate interaction. A 2-tailed significance level of .05 was used for the overall assessment. The significance criterion for each interaction was set to .05/3 = .0167 (Bonferroni correction), and all reported *P* values were 2-tailed. Statistical analyses were performed with the statistical program SPSS (version 23.0; IBM).

Sample Size

The sample size was calculated using the program PASS software (version 11.0; NCSS, LLC). The "two independent proportions" procedure was used. The incidence of hypoxemia during gastroscopy in the nasal cannula group with intravenous anesthesia has been reported to be 16%,[3] and we assumed that the nasal mask would reduce the incidence of hypoxemia from 16% to 8%. With an $\alpha = .05$ and a power of 80%, we estimated that 261 patients per group would be required for our study. We assumed a dropout rate of 10%, leading to a minimal total sample of 574 patients (287 in each group).

RESULTS

Patient Characteristics

The study initially screened 589 patients for gastroscopy. After excluding 15 patients, 574 patients were randomly divided into 2 groups (287 patients each). In the nasal cannula group, 2 patients violated the trial protocol, and 3 patients were excluded due to missing data (Figure 3). Four patients in the nasal mask group were excluded due to violations of the trial protocol. Finally, 565 patients were analyzed, of whom 282 received the nasal cannula and 283 received the nasal mask. Demographic data and baseline characteristics were comparable between the 2 groups. All absolute standardized differences were <16.5% (Table 1).

Primary and Secondary Outcomes

The overall incidence of hypoxemia in this study was 22.8% (129 of 565). The incidence of hypoxemia was lower in the nasal mask group (18%) than in the nasal cannula group (27.7%; RR, 0.65; 95% CI, 0.48–0.89; $P = .006$; Table 2). The absolute risk reduction with nasal mask oxygenation was 9.7%, corresponding to a number needed to treat of 10. The 2 groups did not differ in the incidence of severe hypoxemia (nasal mask, 2.8%; nasal cannula, 5.3%; RR, 0.53; 95% CI, 0.23–1.23; $P = .13$) or the minimum Spo_2 (nasal mask, 95.0 [92–98]; nasal cannula, 95.0 [90–98]; median difference, 0.00; 95% CI, –4.00 to 4.50; $P = .13$). However, we observed that the duration of hypoxemia was significantly shorter in the nasal mask group (18 seconds) than that in the nasal cannula group (32.5 seconds; median difference, –14.50; 95% CI, –22.82 to –1.34; $P = .047$; Table 2). In this study, all patients achieved an OAAS score of 5 after the gastroscopy procedure. No difference was found in the overall incidence of other adverse events between the 2 groups (nasal mask, 20.8%; nasal cannula, 17%; RR, 1.23; 95% CI, 0.87–1.73; $P = .25$). No patient in the study experienced reflux aspiration or laryngospasm, and no patient required tracheal intubation. Table 2 reports the incidences of $Spo_2 \leq 75\%$, duration of hypoxemia >60 seconds, operation time, recovery time, and satisfaction of anesthetists and gastroenterologists.

Emergency Airway Management

A total of 79 of 565 patients (14%) required emergency airway management. The proportion of patients requiring emergency airway management was lower in the nasal mask group (8.8%) than in the nasal cannula group (19.1%; RR, 0.46; 95% CI, 0.30–0.73; $P < .001$; Table 2). In addition, the nasal mask group

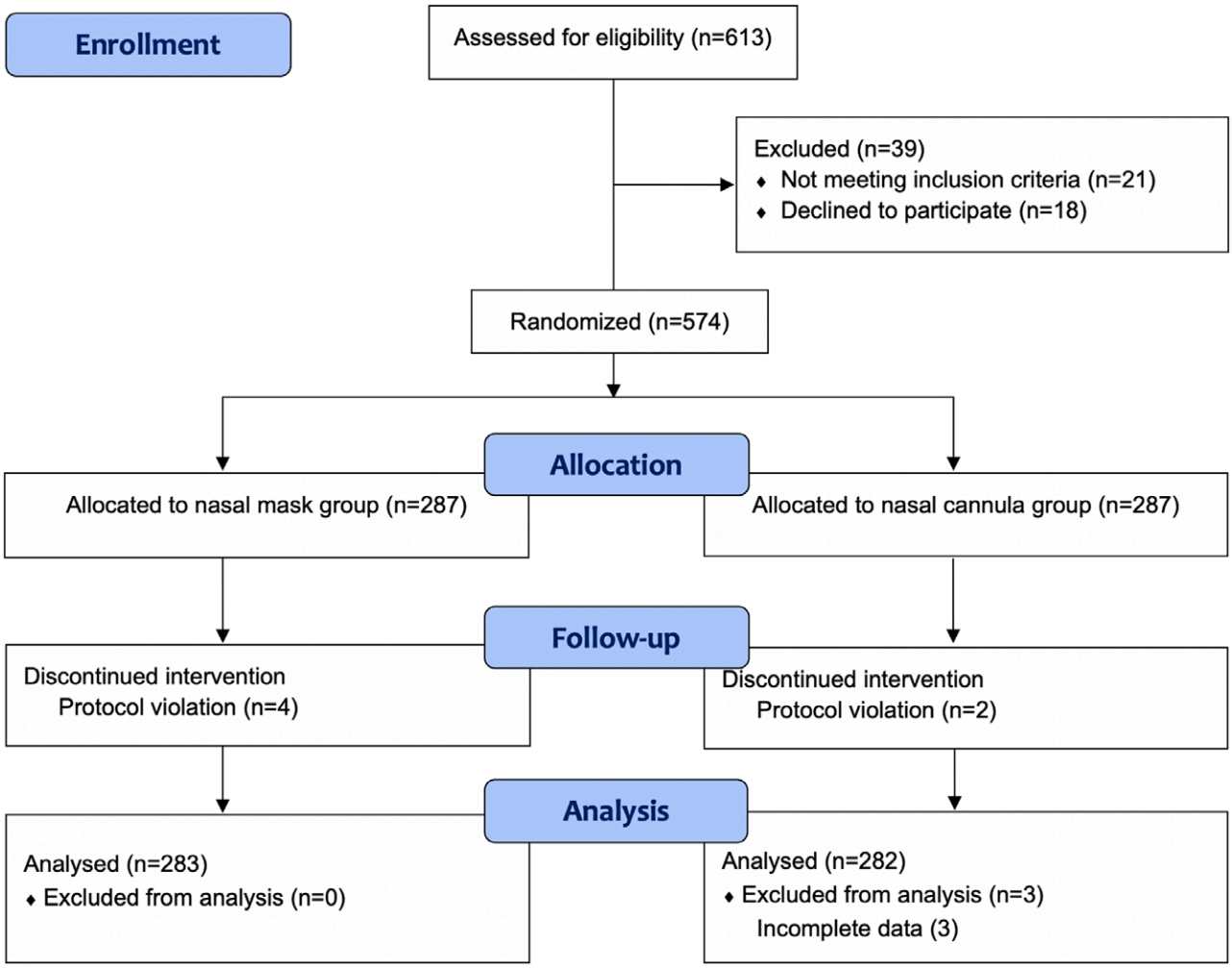

Figure 3. CONSORT diagram of the participant selection protocol. CONSORT indicates Consolidated Standards of Reporting Trials.

Table 1. Baseline Demographic and Clinical Characteristics of the Patients

Variable	Nasal mask, N = 283	Nasal cannula, N = 282	Absolute standardized difference, %[a]
Age, median (IQR), y	49 (39–61)	50 (40–59)	0.2
Male sex, n (%)	141 (49.8)	137 (48.6)	2.4
BMI, median (IQR), kg/m^2	23.1 (20.7–25.9)	23.4 (20.7–25.6)	0.8
<18.5, n (%)	22 (7.8)	19 (6.7)	
18.5 ≤ BMI < 24, n (%)	145 (51.2)	144 (51.1)	
24 ≤ BMI < 28, n (%)	85 (30.0)	90 (31.9)	
≥28, n (%)	31 (11.0)	29 (10.3)	
ASA classification, median (IQR)	1 (1–2)	1 (1–2)	9.1
I, n (%)	186 (65.7)	169 (59.9)	
II, n (%)	87 (30.7)	105 (37.3)	
III, n (%)	10 (3.5)	8 (2.8)	
Propofol dosage, median (IQR), mg	80 (60–110)	80 (70–110)	9.2
Sufentanil, median (IQR), μg	5 (5–5)	5 (5–5)	0
Midazolam, median (IQR), mg	1 (1–1)	1 (1–1)	0

Data are expressed as median (IQR) or number (proportion).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; IQR, interquartile range.
[a]Absolute standardized difference = difference in means or proportions divided by standard error; a value >16.5% is interpreted as a meaningful difference.[13]

showed lower frequencies of oxygen flow increase (15.5% vs 23.8%; RR, 0.65; 95% CI, 0.47–0.92; P = .014) and the jaw-thrust maneuver (8.8% vs 19.1%; RR, 0.46; 95% CI, 0.30–0.72; P < .001). A total of 41 patients (14.5%) in the nasal cannula group required urgent suspension of the endoscopy operation, removal of the endoscope, and ventilation with a facemask, compared with 19 patients (6.7%) in the nasal mask group (RR, 0.46; 95% CI, 0.28–0.78; P = .003).

Table 2. Comparison of Study Outcomes Between the 2 Groups

Assessments	Nasal mask, N = 283	Nasal cannula, N = 282	RR or difference in median (95% CI)	*P*
Primary outcome				
Incidence of hypoxemia, n (%)	51 (18.0)	78 (27.7)	0.65 (0.48–0.89)	.006[a]
Secondary outcomes				
Incidence of severe hypoxemia, n (%)	8 (2.8)	15 (5.3)	0.53 (0.23–1.23)	.13[a]
Spo_2 ≤75%	6 (2.1)	8 (2.8)	0.75 (0.26–2.13)	.58[a]
The duration of hypoxemia >60 s	6 (2.1)	9 (3.2)	0.66 (0.24–1.84)	.43[a]
The duration of hypoxemia, median (IQR), s[b]	18.0 (10.0–38.8)	32.5 (20.0–53.5)	−14.50 (−22.82 to −1.34)	.047[c]
Minimum Spo_2, median (IQR), %	95.0 (92.0–98.0)	95.0 (90.0–98.0)	0.00 (−4.00 to 4.50)	.13[c]
Emergency airway management, n (%)	25 (8.8)	54 (19.1)	0.46 (0.30–0.73)	<.001[a]
Increase the flow of oxygen	44 (15.5)	67 (23.8)	0.65 (0.47–0.92)	.014[a]
Jaw thrust	25 (8.8)	54 (19.1)	0.46 (0.30–0.72)	<.001[a]
Mask-assisted ventilation	19 (6.7)	41 (14.5)	0.46 (0.28–0.78)	.003[a]
Adverse events, n (%)	59 (20.8)	48 (17.0)	1.23 (0.87–1.73)	.25[a]
Cough	50 (17.7)	40 (14.2)	1.25 (0.85–1.82)	.26[a]
Hiccups	9 (3.2)	8 (2.8)	1.14 (0.44–2.86)	.81[a]
Length of procedure, median (IQR), min	6.0 (5.0–8.0)	7.0 (5.0–8.0)	−1.00 (−1.00 to 0.00)	.64[c]
Recovery time, median (IQR), min	2.0 (1.0–3.0)	2.0 (1.0–4.0)	0.00 (0.00–0.00)	.18[c]
The satisfaction of anesthetist, n (%)	272 (96.1)	238 (84.4)	1.14 (1.08–1.20)	<.001[a]
The satisfaction of gastroenterologists, n (%)	270 (95.4)	231 (81.9)	1.17 (1.10–1.24)	<.001[a]

Data are expressed median (IQR) or number (proportion).
Abbreviations: CI, confidence interval; IQR, interquartile range; RR, relative risk; Spo_2, pulse oxygen saturation.
[a]*P* values for χ^2 test.
[b]Data from only 129 patients with hypoxemia are analyzed.
[c]*P* values for Mann-Whitney *U* test.

Assessment of Treatment Effect Heterogeneity

Post hoc analysis demonstrated that age was not an effect modifier for the relationship between nasal mask oxygen and hypoxemia (*P* value interaction term = .74; Supplemental Digital Content 1, Figure S1, http://links.lww.com/AA/D749). Similarly, there were no significant interactions for the relationship between nasal mask oxygen and hypoxemia on ASA physical status and BMI (interaction term *P* = .052 and .08, respectively).

DISCUSSION

This randomized controlled trial assessed the effect of nasal mask oxygenation compared with nasal cannula oxygenation on the incidence of hypoxemia in patients undergoing intravenous anesthesia for gastroscopy. We observed that nasal mask oxygenation led to a significantly lower incidence of hypoxemia than routine nasal cannula oxygenation (18% vs 27.7%). Moreover, nasal mask oxygenation significantly reduced the proportion of patients requiring emergency airway management (8.8% vs 19.1%), and it improved the satisfaction of anesthetists and gastroenterologists compared with the nasal cannula group, without increasing the incidence of other adverse events.

Several studies have described alternative methods to avoid hypoxemia in patients undergoing general anesthesia for gastrointestinal endoscopy procedures. A previous study[6] used 2, 10-Fr suction catheters to adapt a nasopharyngeal catheter, and the researchers evaluated the effectiveness of this catheter for oxygen supply in patients undergoing gastrointestinal endoscopy. They found that nasopharyngeal catheter oxygenation was associated with lower incidence of hypoxemia than a traditional nasal cannula (11.1% vs 40%). However, these observations need to be confirmed in a large sample.

In our study, we adopted an infant mask to supply oxygen through the nose and found that this nasal mask was a good solution to reduce the incidence of hypoxemia. The nasal mask was associated with lower incidence of hypoxemia than a nasal cannula (18.0% vs 27.7%), corresponding to an RR reduction of 35.0%. Besides, nasal mask also significantly decreased the need for maneuvers to maintain free upper airways (8.8% vs 19.1%) and for increasing oxygen flow (15.5% vs 23.8%). The effectiveness of the nasal mask can somewhat be considered similar to the HFNC used in Mazzeffi et al[7] study. The author reported that HFNC oxygenation could reduce the incidence of hypoxemia from 33.1% to 21.2%. Nay et al[14] compared HFNC oxygenation with standard nasal cannula oxygenation in 379 patients having intravenous anesthesia for gastrointestinal endoscopy. They found that HFNC oxygenation significantly reduced the incidence of hypoxemia from 22.9% to 5.8% and decreased frequent need for maneuvers to maintain free upper airways (11.1% vs 32.4%) and for increasing oxygen flow (7.9% vs 23.4%).[14] Our study differs from the Nay et al[14] study in that we only enrolled patients having gastroscopy. Another important difference is that in our study, the initial oxygen flow in nasal mask and nasal cannula group was 4 L/min, while in Nay et al[14] study, the oxygen flow was 70 L/min

in the HFNC group and 8 L/min in the standard nasal cannula group. These differences could have reduced the incidence of hypoxemia in the Nay et al[14] study compared with ours. However, a disposable HFNC oxygen circuit costs much more than a nasal cannula. Besides, an upfront investment of approximately $3500 is required to purchase the delivery system, which may be prohibitively expensive for some hospitals. Lower cost and easier implementation may make the nasal mask oxygenation easier to apply in clinical practice.

In the current study, nasal mask oxygenation reduced the incidence of hypoxemia. However, this does not mean that nasal mask oxygenation benefits all patients undergoing anesthesia for gastroscopy. A previous study found that being older than 65 years, ASA class III, and higher BMI were associated with increased risk of hypoxemia during anesthesia for endoscopic procedures.[15–18] Our subgroup analysis found that the effect of nasal mask oxygen on the occurrence of hypoxemia did not depend on age, ASA physical status, and BMI. However, with the given sample size, the tests for heterogeneity were quite underpowered.

Our study presents several limitations. First, we could not blind medical personnel or patients to group assignment, which may bias our findings. Second, the subgroups of patients over 65 years, patients in ASA class III, and patients with BMI ≥28 kg/m^2 were small. Therefore, further research is needed to explore the risks and benefits of nasal mask in these high-risk patients. Third, we did not control for sedation depth, which has been shown in other work to influence the incidence of hypoxemia.[19] Fourth, the incidence of hypoxemia in the nasal mask group was slightly higher than the incidence reported by previous studies, including the one used to calculate the minimal sample for the present work.

In conclusion, this study demonstrated that nasal mask oxygenation can lead to a lower incidence of hypoxemia than nasal cannula oxygenation in patients undergoing intravenous anesthesia for gastroscopy. The adverse events, such as the incidence of severe hypoxemia and cough, were similar in both groups. In particular, no patient in either group suffered serious adverse events (ie, reflux, aspiration, or tracheal intubation). Based on these findings, the nasal mask could be an effective supplemental oxygen device for gastroscopy. Further studies should focus on identifying specific patient subgroups that may benefit from nasal mask oxygen during gastroscopy.

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DISCLOSURES

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Name: Hui Yang, MD.
Contribution: This author helped design and conduct the study, analyze and interpret the data, and draft and approve the final manuscript.
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Name: Qian Li, MD.
Contribution: This author helped with concept and design, interpretation of the data, critical revision of the manuscript for important intellectual content, and final approval.
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REFERENCES

1. Peery AF, Crockett SD, Murphy CC, et al. Burden and cost of gastrointestinal, liver, and pancreatic diseases in the United States: update 2018. *Gastroenterology.* 2019;156:254.e11–272.e11.
2. Inadomi JM, Gunnarsson CL, Rizzo JA, Fang H. Projected increased growth rate of anesthesia professional-delivered sedation for colonoscopy and EGD in the United States: 2009 to 2015. *Gastrointest Endosc.* 2010;72:580–586.
3. Cai G, Huang Z, Zou T, et al. Clinical application of a novel endoscopic mask: a randomized controlled trial in aged patients undergoing painless gastroscopy. *Int J Med Sci.* 2017;14:167–172.
4. Qadeer MA, Lopez AR, Dumot JA, Vargo JJ. Hypoxemia during moderate sedation for gastrointestinal endoscopy: causes and associations. *Digestion.* 2011;84:37–45.
5. Xiao Q, Yang Y, Zhou Y, et al. Comparison of nasopharyngeal airway device and nasal oxygen tube in obese patients undergoing intravenous anesthesia for gastroscopy: a prospective and randomized study. *Gastroenterol Res Pract.* 2016;2016:2641257.
6. King AB, Alvis BD, Hester D, Taylor S, Higgins M. Randomized trial of a novel double lumen nasopharyngeal catheter versus traditional nasal cannula during total

intravenous anesthesia for gastrointestinal procedures. *J Clin Anesth.* 2017;38:52–56.
7. Mazzeffi MA, Petrick KM, Magder L, et al. High-flow nasal cannula oxygen in patients having anesthesia for advanced esophagogastroduodenoscopy: HIFLOW-ENDO, a randomized clinical trial. *Anesth Analg.* 2021;132:743–751.
8. Oto J, Li Q, Kimball WR, et al. Continuous positive airway pressure and ventilation are more effective with a nasal mask than a full face mask in unconscious subjects: a randomized controlled trial. *Crit Care.* 2013;17:R300.
9. 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.
10. Riphaus A, Geist C, Schrader K, Martchenko K, Wehrmann T. Intermittent manually controlled versus continuous infusion of propofol for deep sedation during interventional endoscopy: a prospective randomized trial. *Scand J Gastroenterol.* 2012;47:1078–1085.
11. Kapoor MC, Rana S, Singh AK, Vishal V, Sikdar I. Nasal mask ventilation is better than face mask ventilation in edentulous patients. *J Anaesthesiol Clin Pharmacol.* 2016;32:314–318.
12. Eberl S, Koers L, van Hooft JE, et al. Sedation with propofol during ERCP: is the combination with esketamine more effective and safer than with alfentanil? Study protocol for a randomized controlled trial. *Trials.* 2017;18:472.
13. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med.* 2009;28:3083–3107.
14. 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;127:133–142.
15. Wani S, Azar R, Hovis CE, et al. Obesity as a risk factor for sedation-related complications during propofol-mediated sedation for advanced endoscopic procedures. *Gastrointest Endosc.* 2011;74:1238–1247.
16. Haines DJ, Bibbey D, Green JR. Does nasal oxygen reduce the cardiorespiratory problems experienced by elderly patients undergoing endoscopic retrograde cholangiopancreatography? *Gut.* 1992;33:973–975.
17. Akhtar S. Pharmacological considerations in the elderly. *Curr Opin Anaesthesiol.* 2018;31:11–18.
18. Kohler M, Mcnicholas WT, Somers VK, Lavie L. Obstructive sleep apnoea syndrome. *Nat Rev Dis Prim.* 2015;1:15015.
19. Zhou X, Li BX, Chen LM, et al. Etomidate plus propofol versus propofol alone for sedation during gastroscopy: a randomized prospective clinical trial. *Surg Endosc.* 2016;30:5108–5116.