Incidence of hypoxemia with high-flow nasal oxygenation versus facemask oxygenation in patients at risk of hypoxemia undergoing bronchoscopy: A randomised controlled trial

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Research Article

Keywords: bronchoscopy, hypoxemia, deep sedation, high-flow nasal oxygenation

Posted Date: August 16th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1903734/v1

Abstract

Background: Patients at high risk of obstructive sleep apnea (OSA) are prone to hypoxemia during sedated bronchoscopy. The present study aimed to investigate whether high-flow nasal oxygenation (HFNO) reduces the incidence of hypoxemia in patients at high risk of OSA undergoing bronchoscopy under deep sedation.

Methods: A total of 176 patients at high risk of OSA who underwent bronchoscopy under deep sedation were randomly assigned into two groups: the HFNO group (humidified oxygen was supplied via a high-flow nasal cannula at a rate of 60 L/min and a concentration of 100%, n = 87) and the Facemask group (oxygen was supplied via tight-fitting facemask at a rate of 6 L/min and a concentration of 100%, n = 89).

Results: Hypoxemia occurred in 4 (4.6%) patients in the HFNO group and 26 (29.2%) patients in the Facemask group ($P < 0.001$). The Facemask group required more jaw thrust maneuvers than the HFNO group (48.3% *vs* 5.7%, $P < 0.001$). A total of 9.0% of the patients in the Facemask group and no one in the HFNO group required bag-mask ventilation ($P = 0.012$).

Conclusions: HFNO can reduce the incidence of hypoxemia and the requirement of airway intervention in patients at high risk of OSA during bronchoscopy under deep sedation.

Trial registration: www.chiCTR.org.cn Identifier: ChiCTR2100044105. Registered 11/03/2021.

Introduction

Flexible bronchoscopy (FB) is commonly performed under anaesthesia or sedation with a higher acceptability [1]. Hypoxemia can occur in 28.8%-56% of patients undergoing sedated bronchoscopy [2, 3]. Patients with obstructive sleep apnea (OSA) [4], male sex [5], obesity [5], older age [5] or hypertension [6] are more prone to hypoxemia. Various measures are taken to reduce the incidence of hypoxemia during sedated bronchoscopy, but the effect is not ideal.

High-flow nasal oxygenation (HFNO) is a strategy that can provide an extremely high flow of heated and humidified gas with adjustable temperature and oxygen concentration through a special nasal cannula [7]. A number of studies have evaluated the efficacy of HFNO during bronchoscopy [8, 9], as it could prevent the loss of end-expiratory lung volume and improve gas exchange and oxygenation [2]. Some studies have focused on the efficacy of HFNO in acute respiratory failure patients [10–12] or lung transplant patients [13], who have an increased risk of hypoxemia, whereas others investigated patients receiving topical anaesthesia [3] or conscious sedation [14, 15] during bronchoscopy. However, no study has compared the efficacy of HFNO with tight-fitting facemask in patients at risk of hypoxemia during bronchoscopy, especially under deep sedation. Therefore, this study was conducted to verify the hypothesis that HFNO has distinct advantages of optimizing oxygenation and preventing desaturation in patients at risk of hypoxemia during deeply sedated bronchoscopy.

Patients And Methods

Design and study subjects

The study was approved by the local ethics committee (IRB-2021-33). All participants signed a written informed consent form prior to the study. A total of 396 patients were screened, among whom 176 patients completed the study and had their results analyzed in the Cancer Hospital of the University of Chinese Academy of Sciences (Zhejiang Cancer Hospital) from March to April, 2021. The study was registered at www.chiCTR.org.cn (ChiCTR2100044105) on 11/03/2021.

Patients undergoing deeply sedated bronchoscopy were recruited for the study. The inclusion criteria included (1) 18 to 80 years of age; and (2) at risk of hypoxemia, defined as having a STOP-BANG (snoring, tiredness, observed apnea, high blood pressure, body mass index [BMI], age, neck circumference, and male sex) score ≥ 3. The exclusion criteria were as follows: (1) American Society of Anaesthesiologists (ASA) class > III; (2) coagulopathy disorders defined by coagulopathy function or a tendency for nose bleeding; (3) severe cardiac disease, including aortic stenosis, mitral stenosis, hemodynamic instability caused by severe arrhythmia, and acute myocardial infarction or cardiac surgery within the last 6 months; (4) severe hypoxemia (SpO_2 < 90% without oxygen supply on admission); (5) upper respiratory tract infection or lung infection; and (6) refusal to participate in this study.

Study protocol

Randomization and blinding

The study flowchart is illustrated in Fig. 1. Patients were randomly assigned to the HFNO group or the Facemask group in a 1:1 ratio by a random number table. The treatment allocation was placed into a sealed, sequentially numbered and opaque envelope. Investigators were blinded to the study protocol and treatment allocation throughout the study. The investigators recorded the patients' demographic information, adverse events, real time oxygen saturation, heart rate and blood pressure on a paper case report form. A black cloth was placed between the patients and the investigators while the monitor was visible to both the investigators and the Anaesthesiologist. The anaesthesiologist noticed every change in oxygen saturation and performed the appropriate intervention. The patients, anaesthesia team, and pulmonologists could not be blinded due to the study design.

Study intervention

The patients' demographic information, such as sex, weight, height, smoking status, present illness and history of past illness, were collected. Additionally, the interincisor distance, thyromental distance, and modified Mallampati score (I-IV) were recorded by the investigators. After successful peripheral intravenous access, all patients, before sedation, received 20 min nebulization with 10 ml of 2% lidocaine via a nebulizer facemask.

The basic oxygen saturation, heart rate, and blood pressure of the patients were recorded by the investigators. Continuous electrocardiography and pulse oximetry were recorded, and the blood pressure of the patients was monitored every 5 min throughout the procedure. Patients in the HFNO group received humidified oxygen at a rate of 60 L/min and a concentration of 100% via a high-flow nasal cannula (AIRVO2, Fisher & Paykel, New Zealand), while those in the Facemask group received oxygen at a flow rate of 6 L/min via a tight-fitting facemask (MedPlus Inc., China) attached to a cycle system (Fig. 2). End-tidal carbon dioxide waveform was monitored to ensure a tight seal was achieved between the patient and the facemask. Patients in both groups were given supplemental oxygen through the corresponding oxygenation methods for 1 min before sedation. Then, single doses of 0.06–0.1 μg/kg sufentanil and 2–3.5 mg/kg propofol were administered slowly by an anaesthesiologist based on the body weight, age and comorbidities of the patients. The Ramsay sedation score (RSS) was used to assess the level of sedation. Bronchoscopy was performed through the nasal route in a supine position when the RSS > 4, and 3 ml of 2% lidocaine was sprayed locally over the vocal cords and the trachea. An RSS > 4 was maintained throughout the procedure, and 0.05 mg/kg propofol was given to achieve adequate sedation. The total dose of propofol used and adverse reactions of patients, such as cough, oppositional behavior, tachycardia, bradycardia, hypotension, were recorded. Tachycardia was defined as a heart rate of more than 100 beats per minute or an increase of > 25% from baseline; bradycardia was defined as a heart rate of less than 50 beats per minute or a decrease of > 25% from baseline; and hypotension was defined as a systolic blood pressure less than 90 mmHg or a decrease of > 20% from baseline.

Postanesthesia care unit (PACU)

Patients were transferred to the PACU if their vital signs were stable. All patients received oxygen at 3 L/min through a nasal catheter. After at least 30 min of observation in the PACU, patients were allowed to leave the clinic after their post anaesthetic Aldrete recovery score was assessed. A score of 9 or 10 was required to be discharged. Additionally, airway obstruction and hypoxemia in the PACU were recorded by the investigators. Airway obstruction was defined as the tongue falling back against the posterior pharynx, which could be alleviated by the combination of jaw thrust and head-tilt maneuvers and insertion of an oral/nasal-pharyngeal airway. HFNO-related side effects such as dry nose, sore throat and headache were recorded 30 min after bronchoscopy in the HFNO group.

Outcomes and airway interventions

The primary outcome of this study was the incidence of hypoxemia in the two groups. The secondary outcomes were airway interventions.

Hypoxemia was defined as an SpO_2 < 90% and was divided into moderate hypoxemia (75% ≤ SpO_2 < 90%, lasting < 60S) and severe hypoxemia (SpO_2 < 75% or 75% ≤ SpO_2 < 90% lasting > 60S), as recommended by the World Society of Intravenous Anaesthesia (SIVA) International Sedation Task Force [16]. The airway was opened in all patients by the jaw thrust maneuver when the SpO_2 dropped below 95%. When moderate hypoxemia occurred, treatments including an increase in oxygen flow from 6 L/min

to 10 L/min and airway opening by the jaw thrust maneuver were provided to the Facemask group, while only the latter was given to the HFNO group. For severe hypoxemia, patients received bag-mask ventilation. If oxygenation still did not improve, endotracheal intubation was performed by the anaesthesiologist at his or her own discretion.

Statistical analysis

The sample size was calculated by PASS version 15.0 (NCSS, LLC, Kaysville, UT, USA). According to the results of our preliminary experiment, the percentages of hypoxemia in the HFNO group and Facemask group were 5% and 26%, respectively. Herein, we estimated that a sample size of 81 subjects per group would provide 90% power with an alpha of 0.01 using the two independent proportions of Z-tests. To compensate for possible dropouts, the sample size was increased to 180 subjects (90 per group).

IBM SPSS Statistics for Windows version 26.0 (IBM Corp., Armonk, NY, USA) was used for the statistical analyses. Categorical variables are presented as numbers (%), and numerical variables are presented as the mean (standard deviation) or median (interquartile range). Numerical variables were analyzed with the Student *t* test if normally distributed and the Mann-Whitney U test if not. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. Bonferroni correction was made for multiple hypothesis tests. The odds ratio (OR) and 95% confidence interval (CI) of the variables possibly associated with the incidence of hypoxemia were estimated using multivariate binary logistic regression after adjusted for age, sex, BMI, hypertension, snoring, neck circumference, modified Mallampati score, propofol dose and sufentanil dose. Differences were considered statistically significant if $P < 0.05$.

Results

Descriptive data

A total of 396 patients were screened for eligibility, 180 of whom were included in the study. Four patients were excluded because of missing data. The patient characteristics were well balanced between groups (Table 1).

Table 1
The demographic information and medical history of the patients

	HFNO Group (n = 87)	Facemask Group (n = 89)
Age (yrs)	64.2 ± 9.3	63.6 ± 7.7
Sex	74 (85.1)	73 (82.0)
Male, no. (%)	13 (14.9)	16 (18)
Female, no. (%)		
Weight (kg)	64.0 ± 9.9	65. 6 ± 9.1
BMI (kg/m^2)	23.6 ± 2.8	23.8 ± 2.9
ASA physical status [a], I/II/III	29/55/3	29/59/1
Smoking Status	20 (0 to 40)	24 (0 to 40)
History (pack years)		
Current Smoker, no. (%)	20 (23.0)	30 (33.7)
Past Smoker, no. (%)	39 (44.8)	29 (32.6)
Never Smoked, no. (%)	28 (32.2)	30 (33.7)
Comorbidity	32 (36.8)	47 (52.8)
Hypertension, no. (%)	5 (5.7)	2 (2.2)
Diabetes, no. (%)	2 (2.3)	3 (3.3)
Heart disease, no. (%)	0 (0)	0 (0)
Asthma, no. (%)	2 (2.3)	1 (1.1)
COPD, no. (%)	17 (19.5)	15 (16.9)
Lung cancer, no. (%)	4 (4.6)	0 (0)
Esophagus Cancer, no. (%)		
STOP-Bang Questionnaire	3 (3 to 4)	3 (3 to 4)
Total scores		
Snoring, no. (%)	68 (78.2)	71 (79.8)
Neck circumference > 40cm, no. (%)	12 (13.8)	12 (13.5)
Modified Mallampati score [b], I/II/III/IV	44//34/9/0	46/31/11/1

	HFNO Group (n = 87)	Facemask Group (n = 89)
Mouth opening [c], 1/2/3	0/1/86	0/0/89
Thyromental Distance [d], I/II/III	77/8/2	77/7/5
Data are presented as numbers (%), means ± standard deviations or medians (interquartile ranges).		
Abbreviation: BMI: body mass index; COPD: chronic obstructive pulmonary disease; OSA: obstructive sleep apnea.		
[a] ASA physical status: I: normal healthy patient, II: patient with mild systemic disease that does not limit physical activity, III: patient with severe systemic disease.		
[b] Modified Mallampati score: Class I: the entire palatal arch is visible down to the bases of the pillars, Class II: the upper part of the faucial pillars and most of the uvula are visible, Class III: only the soft and hard palates are visible, Class IV: only the hard palate is visible.		
[c] Mouth opening:1, one finger; 2, two fingers; 3, three fingers.		
[d] Thyromental Distance: I, > 6.5 cm; II, 6-6.5 cm; III, < 6 cm.		

Main Findings

Additionally, the Facemask group had a higher incidence of hypoxemia (29.2%) than the HFNO group (4.6%) (odds ratio, 0.093; 95%CI, 0.028 to 0.313; $P < 0.001$) (Table 2). Among them, 29.2% of the patients in the Facemask group and 4.6% of the patients in the HFNO group had moderate hypoxemia, while 9% of the patients in the Facemask group and no patient in the HFNO group developed severe hypoxemia. The HFNO group required fewer jaw thrust maneuvers than the Facemask group (odds ratio, 0.041; 95%CI, 0.012 to 0.134; $P < 0.001$). None of the patients in the HFNO group while 9.0% in the Facemask group required bag-mask ventilation ($P = 0.012$). None of the patients received tracheal intubation in either of the two groups.

Table 2
Primary outcome and airway interventions during bronchoscopy

	HFNO Group (n = 87)	Facemask Group (n = 89)	Odds Ratio (95%CI)	*P* value
Primary outcome Nil, no. (%) [a]	83 (95.4)	63 (70.8)	-	< 0.001 [c]
Hypoxemia, no. (%) [b]	4 (4.6)	26 (29.2)	0.093 (0.028 to 0.313)	
Moderate hypoxemia, no. (%)	4 (4.6)	18 (20.2)	0.163 (0.048 to 0.547)	0.001 [c]
severe hypoxemia, no. (%)	0 (0)	8 (9.0)	-	0.005 [c]
Interventions				
Jaw thrust maneuver, no. (%)	5 (5.7)	43 (48.3)	0.041 (0.012 to 0.134)	< 0.001
Increase the flow of oxygen, no. (%)	0 (0)	21 (23.6)	-	< 0.001
Mask ventilation, no. (%)	0 (0)	8 (9.0)	-	0.012
Intubation, no. (%)	0 (0)	0 (0)	-	NS
Data are presented as numbers (%).				
[a] Nil was defined as $SpO_2 \geq 90\%$.				
[b] Hypoxemia was defined as an $SpO_2 < 90\%$ and was divided into moderate hypoxemia ($75\% \leq SpO_2 < 90\%$, lasting < 60 s) and severe hypoxemia ($SpO_2 < 75\%$ or $75\% \leq SpO_2 < 90\%$ lasting > 60 s).				
[c] $P < 0.0167$ was considered statistically significant after Bonferroni correction.				

No significant difference was detected in adverse reactions, including tachycardia, bradycardia, hypotension, and myoclonus during bronchoscopy between the two groups (Table 3). Moreover, none of the patients in either group had any delays in recovery, cardiovascular collapse, or cardiac arrest. Additionally, there was no significant difference in airway obstruction or the incidence of hypoxemia in the PACU between the two groups. No HFNO-related side effects, such as dry nose, sore throat or headache, were observed in the HFNO group.

Table 3
Adverse events during bronchoscopy

	HFNO Group (n = 87)	Facemask Group (n = 89)	*P* value
Tachycardia, no. (%) [a]	32 (36.8)	30 (33.7)	0.670
Bradycardia, no. (%) [b]	4 (4.6)	1 (1.1)	0.351
Hypotension, no. (%) [c]	42 (48.3)	37 (41.6)	0.371
Recovery delay, no. (%) [d]	0 (0)	0 (0)	NS
Cardiovascular collapse, no. (%) [e]	0 (0)	0 (0)	NS
Cardiac arrest, no. (%) [f]	0 (0)	0 (0)	NS
In PACU	8 (9.2)	15 (16.9)	0.132
Airway obstruction, no. (%) [g]	0 (0)	4 (4.5)	0.135
Hypoxemia, no. (%)			

Data are presented as numbers (%).

[a] Tachycardia: a heart rate of more than 100 beats per minute or an increase of > 25% from baseline.

[b] Bradycardia: a heart rate of less than 50 beats per minute or a decrease of > 25% from baseline.

[c] Hypotension: a systolic blood pressure less than 90 mmHg or a decrease of > 20% from baseline.

[d] Recovery delay: failure to return to baseline clinical status within 2 hours.

[e] Cardiovascular collapse: clinical evidence of inadequate perfusion.

[f] Cardiac arrest: absence of pulse and loss of heart function.

[g] Airway obstruction: the tongue falling back against the posterior pharynx, which could be alleviated by the combination of jaw thrust and head-tilt maneuvers and insertion of an oral/nasal-pharyngeal airway.

The propofol and sufentanil dosages and the duration of bronchoscopy between the two groups were not significantly different (Table 4). Furthermore, the groups did not differ in the patients' hemodynamic signs during bronchoscopy (Table 5). The lowest oxygen saturation of the Facemask group was significantly lower than that of the HFNO group ($P < 0.001$). In the PACU, patients in the HFNO group had a higher oxygen saturation than those in the Facemask group, which could be explained by their higher oxygen reserves during bronchoscopy.

Table 4
Procedural sedation medications and duration of bronchoscopy

	HFNO Group (n = 87)	Facemask Group (n = 89)	*P* value
Total Propofol dose (mg)	176.8 ± 39.0	172.4 ± 31.9	0.411
Total Propofol dose (mg/kg)	2.8 ± 0.5	2.6 ± 0.4	0.064
Sufentanil dose (μg/kg)	0.07 ± 0.01	0.07 ± 0.02	0.323
Duration of bronchoscopy(s) [a]	300 (214 to 363)	300 (180 to 435)	0.513

Data are presented as means ± standard deviations or medians (interquartile ranges).

[a] Duration of bronchoscopy was the duration between the insertion of the bronchoscope to the removal of the bronchoscope.

Table 5
Hemodynamic findings before bronchoscopy, after bronchoscopy and in the PACU

	HFNO Group (n = 87)	Facemask Group (n = 89)	*P* value
Before bronchoscopy	107.0 ± 13.5	111.3 ± 38.7	0.330
Mean BP (mmHg)	80.2 ± 16.0	77.2 ± 15.3	0.206
Heart rate (bpm)	99 (97 to 100)	99 (98 to 100)	0.036
Oxygen saturation (%)	100 (98 to 100)	94 (89 to 100)	< 0.001
During bronchoscopy			
Lowest oxygen saturation (%)			
After bronchoscopy	90.7 ± 15.0	93.7 ± 15.3	0.185
Mean BP (mmHg)	83.2 ± 13.2	80.8 ± 13.8	0.236
Heart rate (bpm)	100 (99 to 100)	100 (99 to 100)	0.064
Oxygen saturation (%)			
In PACU	91.0 ± 38.7	88.2 ± 11.7	0.512
Mean BP (mmHg)	74.9 ± 12.6	74.4 ± 12.0	0.782
Heart rate (bpm)	100 (99 to 100)	99 (98 to 100)	0.005
Oxygen saturation (%)			
Data are presented as means ± standard deviations or medians (interquartile ranges).			
Abbreviation: BP: blood pressure; PACU: postanesthesia care unit.			

Discussion

This randomised controlled study showed that the incidence of hypoxemia and the requirement of airway interventions such as jaw thrust maneuvers and bag-mask ventilation in patients at risk of hypoxemia were significantly reduced by HFNO during deeply sedated bronchoscopy.

HFNO can rapidly wash out CO_2 in the nasopharyngeal dead space with a high flow of oxygen [17], which can reduce the dead space and generate 3–7 cmH_2O positive end-expiratory pressure, thereby increasing the end-expiratory lung volume, reopening the alveoli and preventing atelectasis [18]. Additionally, it can reduce the resistance of the upper respiratory tract and reduce respiratory work [19, 20]. Consequently, HFNO can optimise oxygenation and prevent desaturation in patients undergoing deeply sedated bronchoscopy.

Our results are consistent with previous studies showing that HFNO plays an important role in oxygenation. Previous studies have shown that HFNO is a practical method for preoxygenation during intubation [21–24]. In addition, HFNO significantly decreases the incidence of hypoxemia during sedated gastroscopy or colonoscopy [25–29]. As hypoxemia is more likely to develop during bronchoscopy, a number of studies have evaluated the safety and efficacy of HFNO during bronchoscopy. However, no study has compared the effect of HFNO with facemask in patients at risk of hypoxemia undergoing deeply sedated bronchoscopy.

HFNO costs approximately ten times as much as the facemask technique; thus, it is impractical to apply it for all patients undergoing bronchoscopy, and it is essential to identify patients at high risk of developing hypoxemia. The STOP-BANG questionnaire is a favored, straightforward, effective and highly sensitive screening tool to identify patients with OSA [30, 31]. It consists of eight items with yes or no answers related to the clinical features of OSA such as snoring, male sex, older age, higher BMI, hypertension. It was reported that when undergoing intravenous anaesthesia, patients with a STOP-BANG score ≥ 3, had a higher incidence of hypoxemia than those with a STOP-BANG score < 3 [32]. Therefore, the STOP-BANG questionnaire was chosen to screen patients at risk of hypoxemia.

In the present study, the occurrence of hypoxemia was 29.2% in the Facemask group, which was lower than that reported previously [33], which might be related to the higher oxygen flow and the different sedatives used. Additionally, propofol is commonly used as a sedative alone or in combination with opioids during bronchoscopy owing to its properties of rapid onset and smooth recovery [34–37]. As reported, the dose of propofol administered manually was lower than that administered by continuous infusion pump [37–39], nevertheless, both sedation regimens had similar good controllability [40]. Due to the short duration of bronchoscopy in our center, a single dose of propofol administered manually was chosen in this study.

The limitations of this study are as follows: to avoid increasing the trauma and economic burden of patients, arterial blood analysis was not performed; thus, the pH, PaO_2, and $PaCO_2$ between the two groups could not be compared. Therefore, whether HFNO has an effect on the retention of carbon dioxide within a short period needs further exploration. As the gold standard for diagnosing OSA, polysomnography was not conducted; thus, few data could be provided about the exact number of patients with OSA. The respiratory rate and tidal volume were not monitored, which made it hard to explain the underlying cause of hypoventilation. In addition, several studies have demonstrated that an increase in the flow rate of HFNO can yield a higher FiO_2 [41]. Moreover, a flow rate of > 50 L/min is advisable to obtain the maximal effect of oxygenation. Therefore, an oxygen flow rate of 60 L/min was chosen for the HFNO group; however, such a high flow rate has the potential to cause discomfort of patients and waste of oxygen. Therefore, the optimal flow rate in bronchoscopy under deep sedation needs further investigation.

Conclusions

In conclusion, HFNO significantly reduced the incidence of hypoxemia and the requirement of airway interventions in patients at risk of hypoxemia during bronchoscopy under deep sedation. The STOP-BANG questionnaire can be used to identify patients suitable for HFNO, given its additional cost. These results might modify our clinical practice.

Abbreviations

ASA: American Society of Anesthesiologists; BMI: body mass index; CI: confidence interval; COPD: chronic obstructive pulmonary disease; HFNO: high-flow nasal oxygenation; NRS: numerical rating scale; OR: odds ratio; OSA: obstructive sleep apnea; PACU: postanesthesia care unit; RSS: Ramsay sedation score; STOP-BANG: snoring, tiredness, observed apnea, high blood pressure, body mass index, age, neck circumference, and male sex.

Declarations

Ethics approval and consent to participate: The study was approved by the local ethics committee of the Cancer Hospital of the University of Chinese Academy of Sciences (Zhejiang Cancer Hospital) (IRB-2021-33) and registered at www.chiCTR.org.cn (ChiCTR2100044105) on 11/03/2021. All participants signed a written informed consent form prior to the study. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication: The participants had informed consent for publication.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare they have no competing interests.

Funding: This work was supported by the Basic Public Welfare Research Project in Zhejiang Province (Grant number LGD20H010001).

Authors' contributions: WZ and JLW contributed substantially to the design and conduct of the study, data collection, wrote the first draft of manuscript. SF, JMZ, SNC and JF contributed to recruitment of the patients and data collection. YJZ contributed to data collection and statistical analysis. XZC and KJX contributed to the study design and provided revision to the manuscript. All authors read and approved the final manuscript.

Acknowledgements: The authors thank the staff of the Department of Anaesthesiology and the Department of Endoscopy, Cancer Hospital of the University of Chinese Academy of Sciences (Zhejiang Cancer Hospital), for their help and cooperation in this study.

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Figures

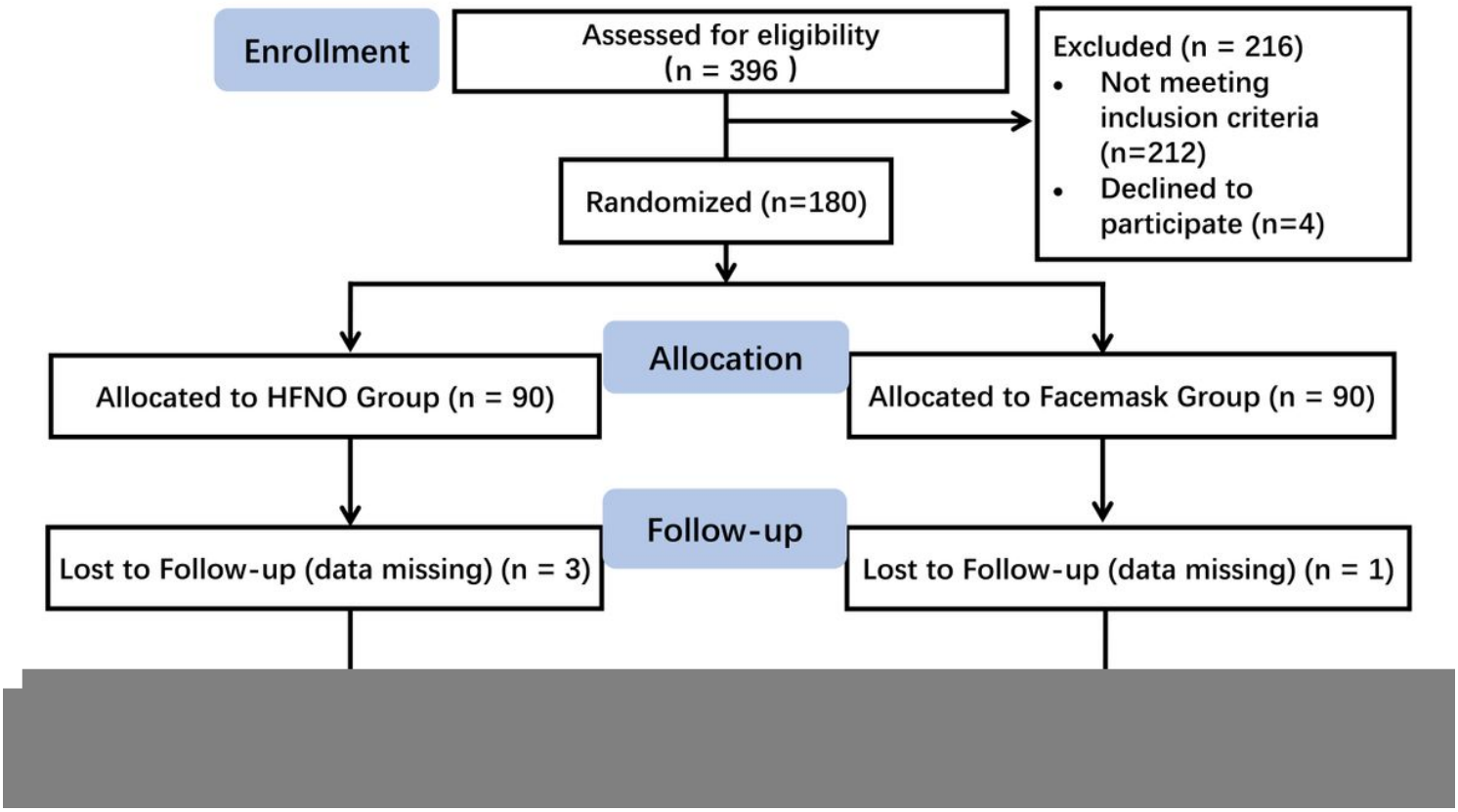

Figure 1

Consolidated Standards of Reporting Trials (CONSORT) flowchart of patient recruitment.

Figure 2

The high-flow nasal cannula and endoscopic facemask. a and b: high-flow nasal oxygenation device; c and d: endoscopic facemask used in flexible bronchoscopy. Bronchoscopy was performed through the nasal route in a supine position.