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High-flow nasal cannula oxygen therapy versus conventional oxygen therapy in patients undergoing bronchoscopy: a retrospective study

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Abstract

Background Patients undergoing bronchoscopy, particularly those with pre-existing hypoxemia, face a significant risk of further deterioration in their oxygen saturation levels. This heightened risk necessitates the provision of supplemental oxygen therapy throughout the procedure, rendering it mandatory. High-flow nasal cannula (HFNC) has been widely employed in the management of hypoxemic acute respiratory failure (ARF) in adults. Based on this, HFNC has been used in endoscopic procedures, but there are still few studies on HFNC in fiberoptic bronchoscopy (FOB) patients. The purpose of this study was to evaluate the comparative efficacy of HFNC with nasal cannula oxygen in maintaining adequate oxygen saturation during fiberoptic bronchoscopy in patients with pre-existing hypoxemia.

Methods We retrospectively investigated 232 patients with hypoxemia who underwent bronchoscopy between January 2018 to August 2023 who received either HFNC or nasal cannula oxygen supplementation. The control group received nasal cannula oxygen, and the observation group received HFNC. The changes of oxygen saturation, heart rate, blood pressure and adverse events during the operation were compared between the two groups.

Results The patients were divided into the HFNC ($n=78$) and nasal cannula oxygen ($n=154$) groups. During FOB, although the lowest oxygen saturation (SpO_2) was similar in both groups (intraoperative minimum SpO_2 was defined as the lowest value of SpO_2 occurring between the start of anesthesia and the end of the operation), the occurrence of the lowest $SpO_2<90\%$ was significantly lower in the HFNC group (3.8% vs. 17.5%, $p=0.003$). No serious complications were reported in either group, however, the overall incidence of general adverse events was 7.7% and 20.1% in the HFNC and conventional oxygen therapy (COT) groups, respectively ($p=0.015$). Multifactorial analysis showed that higher arterial partial pressure of oxygen versus the fraction of inspired oxygen (PaO_2/FiO_2; P/F) was a protective factor against desaturation events ($p=0.032$, OR = 0.990, 95% CI: 0.982–0.999). In patients with baseline $PaO_2/FiO_2 \geq 200$ mmHg, the HFNC group exhibited smoother vital sign changes from pre-procedure to the end of bronchoscopy, although there were no significant differences between the two groups regarding the rates of deoxygenation events as well as adverse events.

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Conclusion The use of HFNC therapy can effectively reduce the incidence of $SpO_2 < 90\%$ during bronchoscopy in patients with hypoxemia. Additionally, HFNC significantly reduces the overall incidence of adverse events compared to COT. In patients with milder hypoxemia, its advantages in maintaining operational stability during bronchoscopy should not be overlooked.

Keywords High-flow nasal cannula, Bronchoscopy, Nasal cannula, Hypoxemia

Introduction

Fiberoptic bronchoscopy (FOB) is widely employed for the diagnosis and treatment of chest diseases. However, during the operation, the endoscope occupies approximately 10–15% of the cross-sectional area of the trachea. Additionally, the fiberscope itself may cause some stimulation to the airway, potentially leading to laryngeal and bronchial spasms, which could aggravate airway stenosis. Furthermore, patients who require FOB frequently present with various comorbid respiratory diseases, which can pose additional challenges to gas exchange in the lungs. Consequently, an unavoidable decline in oxygen saturation or even severe hypoxemia may occur during the procedure. In patients underlying hypoxemia, the partial pressure of oxygen (PaO_2) can drop by 10–20 mmHg [1], significantly increasing the risk of respiratory failure.

High-flow nasal cannula (HFNC) therapy is a simple and very effective oxygenation technique. It can regulate the fraction of inspired oxygen (FiO_2) more precisely than traditional nasal cannula oxygenation. The high flow rate of gas applied creates pressure on the airway, generating a positive end-expiratory pressure, which increases the end-expiratory lung volume and promotes alveolar re-expansion, as well as decreases the physiologic dead space and improves the efficiency of ventilation [2, 3]. In addition, Parke R L et al. found that HFNC, greater airway pressure is generated with the mouth closed than with the mouth open, resulting in a more positive end-expiratory pressure [4]. HFNC has been proven to be an effective treatment for hypoxemic acute respiratory failure (ARF), European Society of intensive Care Medicine and European Respiratory Society's Clinical Practice Guidelines recommend the use of HFNC in case of hypoxic ARF [5, 6]. Meanwhile, several studies have investigated the use of HFNC during FOB, and it is useful in preventing the worsening of ARF during operations [7–9]. However, sufficient evidence regarding the efficacy of HFNC's role compared to other respiratory strategies during FOB is lacking.

Several studies have evaluated the efficacy of HFNC therapy during FOB, demonstrating its ability to improve oxygenation relative to conventional oxygen therapy (low-flow oxygenation) in the general population of patients requiring bronchoalveolar lavage (BAL) or endobronchial ultrasound-guided trans-bronchial needle aspiration (EBUS-TBNA) [9, 10]. HFNC therapy reduces the incidence of hypoxemia during bronchoscopy in patients at risk of hypoxemia when compared to the oxygen mask [11], whereas in patients with moderate-to-severe hypoxemia undergoing bronchoscopy, non-invasive mechanical ventilation is superior to HFNC in terms of oxygenation adequacy and stability [12]. However, information is still very scarce about the eventual better advantages of one strategy compared to another, which prevents the possibility of providing a clear or definitive recommendation on the use of an oxygenation strategy over another one. In parallel, no studies have been conducted to compare the efficacy of nasal cannula oxygenation with HFNC in hypoxemic patients undergoing FOB.

In clinical work, we found that HFNC seemed to help us perform better than nasal cannula oxygen. Therefore, the purpose of this study was to evaluate whether HFNC therapy can better maintain oxygenation compared with nasal cannula oxygen in hypoxemic patients during bronchoscopy. This evaluation aimed to assist clinicians in selecting a safer and more effective respiratory support method during the procedure, thus reducing the potential risks associated with the operation.

Methods

Research design

This retrospective, observational, single-centre study, was approved by the Ethics Committee of Union Hospital of Tongji Medical College, Huazhong University of Science and Technology (No. 816 of 2023) and was conducted in accordance with the Helsinki Declaration. The requirement for written informed consent was waived due to the retrospective nature of the study.

Patients

We included hospitalised patients who attended the Department of Respiratory and Critical Care Medicine, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, China, from January 2018 to August 2023. Patients who met the following four criteria were included: (1) hypoxemic respiratory failure with a $PaO_2/FiO_2 \leq 300$ mmHg before the bronchoscopy examination; (2) $SpO_2 > 90\%$ under supplemental oxygen; (3) patients receiving oxygen via a HFNC or nasal cannula; (4) bronchoscopy performed through the nasal route. Patients were excluded if any of the following criteria were met: (1) receiving other forms of non-invasive or invasive ventilation; (2) hypercapnic respiratory failure

with an arterial $PaCO_2 \geq 45$ mmHg; (3) presence of nasal polyp, nasal hemorrhage or bleeding tendencies, nasal trauma, nasal deformity, and inflammation of the nasal cavity.

The patients were categorised into two groups: the HFNC therapy and conventional oxygen therapy (COT) groups. Oxygen was administered via a standard nasal cannula in the COT group. Prior to all operations, we would use nasal cannula oxygen if it was relatively easy to maintain $SpO_2 > 90\%$ for more than 10 min. After a comprehensive assessment of the patient's general condition and nutritional status, as well as the failure of COT to achieve a steady state of oxygenation, we will consider the adoption of HFNC. All patients received local anesthesia before undergoing bronchoscopy examination. Each patient was administered 10 mL of 2% lidocaine by nebulized inhalation.

Data collection

We retrieved and reviewed the medical records of the included patients through the hospital's electronic medical record system. The following baseline characteristics were recorded: age, sex, height, weight, body mass index (BMI), smoking history, history of hypertension, and pulmonary comorbidities. Results of the preoperative arterial blood gas analysis were also recorded and used to calculate the baseline PaO_2/FiO_2 ratio (P/F ratio), which was categorised into three stages of hypoxemia severity according to Berlin's definition of acute respiratory distress syndrome: (mild, (200 < P/F ratio ≤ 300 mmHg), moderate, (100 < P/F ratio ≤ 200 mmHg), and severe, (P/F ratio ≤ 100 mmHg). We also recorded the main reason for the occurrence of hypoxemia in the patient, as well as the specific bronchoscopy procedures performed. Throughout the operation, each patient would be monitored continuously for pulse oximetry, heart rate, heart rhythm, respiratory rate, and blood pressure.

In addition, we recorded the following parameters before and after the operation: the lowest value of SpO_2 during the operation, SpO_2, heart rate, blood pressure, oxygen flow rate, and FiO_2. If the patient was receiving oxygen through a nasal cannula, the FiO_2 (%) was calculated according to a simple formula: FiO_2 (%) = 21 + 1×oxygen flow rate (L/min). For example, 24% for 1 L/min, 28% for 2 L/min, and so on. When there was a significant decrease in oxygen saturation (absolute decrease in $SpO_2 > 4\%$, or $SpO_2 < 90\%$ that persisted for more than 1 min), we adjusted the FiO_2.

Moreover, we investigated adverse events during the operation. Serious adverse events include severe arrhythmia, sudden cardiac arrest, severe laryngeal oedema (laryngeal obstruction of the third degree or higher), and respiratory arrest. General adverse events include blood pressure fluctuations (hypertension [systolic blood pressure > 150 mmHg in patients without history of hypertension; 30% above basal blood pressure in patients with hypertension], hypotension [systolic blood pressure < 90 mmHg in patients without history of hypotension; 30% below basal blood pressure in patients with hypotension]), bradycardia (heart rate < 60 beats/min; 10% below basal heart rate in patients with bradycardia), tachycardia (heart rate > 100 beats/min; 20% above basal heart rate in patients with tachycardia), bucking, and chest distress. The number of patients who experienced operational interruptions and required escalation of respiratory support during the operation was also recorded.

Statistical analysis

Based on previous studies, the incidence of deoxygenation events in the HFNC group versus the COT group was divided into approximately 5% and 29% [11, 13]. We set an alpha of 0.01 and a power of 0.9 to calculate a minimum sample size of approximately 70 in each group.

Statistical analyses were performed using the SPSS statistical software package, version 25.0 for Windows. Categorical variables were presented as percentages and analysed by the chi-square test, corrected chi-square test, or Fisher's exact test. The Shapiro–Wilk test was performed to test whether the measures conformed to a normal distribution. Continuous variables were presented as the mean ± standard deviation (SD) or median and interquartile range (IQR), and comparisons were made using either the independent t-test or Mann–Whitney test, depending on the normality of the distribution. Independent predictors associated with deoxygenation events in patients with hypoxemia during FOB were first analysed using univariate analysis. Variables that were statistically significant ($p \leq 0.1$) or potentially clinically significant in the univariate analysis were included in the multivariate binomial logistic regression analysis. All statistical tests were two-tailed, and $P < 0.05$ was considered statistically significant.

Results

We screened 289 patients with hypoxemia who underwent FOB between January 2018 and August 2023. Among them, 9 patients were underwent oral bronchoscopy, 12 patients received respiratory support other than HFNC or nasal cannula, 3 patients had SpO_2 values < 90% under oxygenation, and 4 patients received general anesthesia. Therefore, 28 patients were excluded based on the exclusion criteria. Additionally, 29 patients had incomplete records of the operation. Finally, 232 patients were enrolled in the analysis (Fig. 1). These patients were divided into the HFNC ($n = 78$) and the COT ($n = 154$) groups according to the mode of respiratory support.

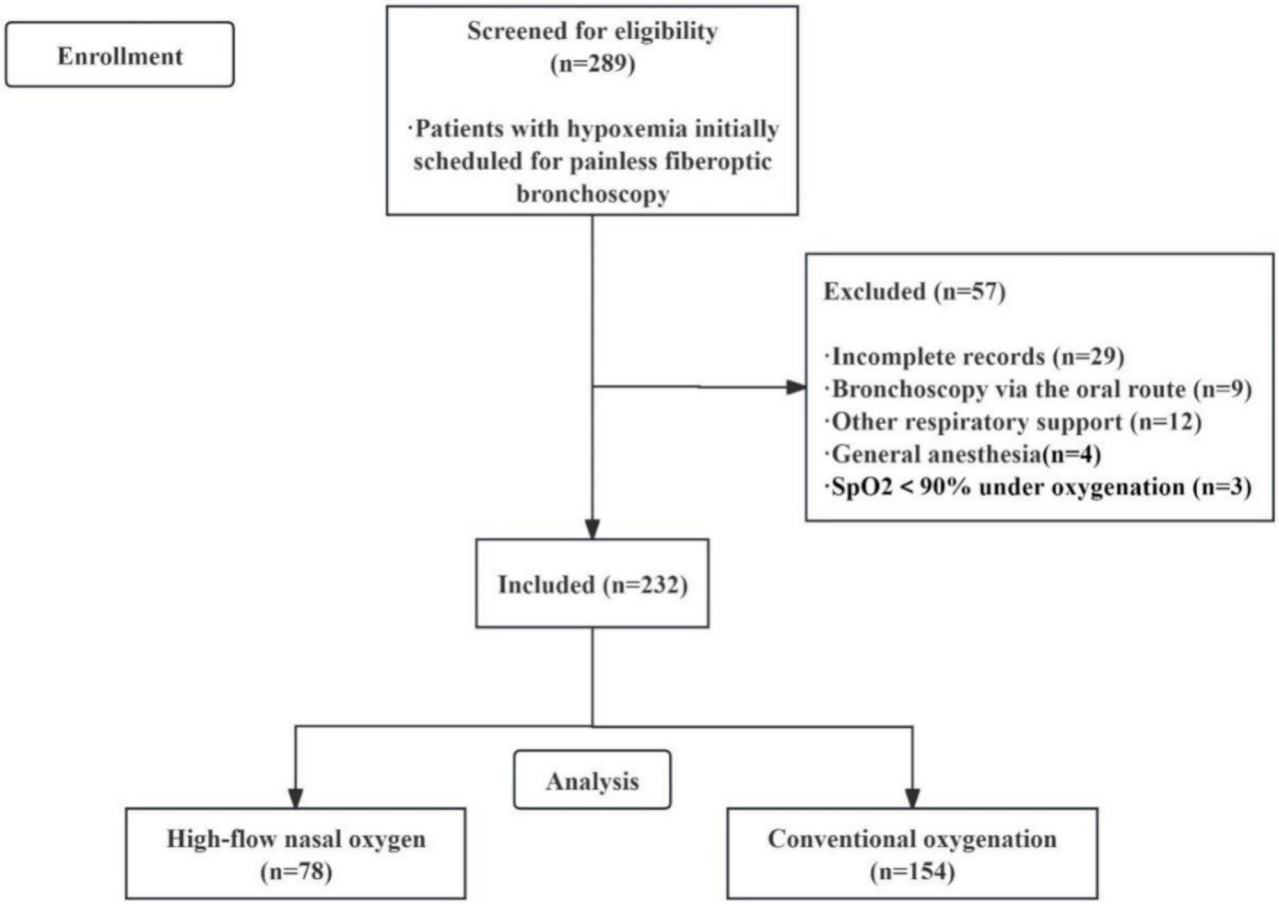

Fig. 1 Flow diagram of patient selection

The baseline characteristics of the patients are presented in Table 1. Underlying pulmonary diseases refer to chronic diseases of the lungs, mainly including interstitial lung disease (ILD), chronic obstructive pulmonary diseases (COPD), asthma, lung cancer, old pulmonary tuberculosis, and bronchiectasis, which were categorized as 0, 1, or ≥2 based on the number of pulmonary comorbidities. The main indications for bronchoscopy were pneumonia, COPD/asthma, ILD, lung cancer, and bronchiectasis. Bronchoscopy procedures included BAL, BAL combined with bronchial brushing, inspection only, transbronchial lung biopsy (TBLB), and EBUS-TBNA. At study entry, gender, age, BMI, smoking history, indications for bronchoscopy, and the types of bronchoscopy procedures were comparable between both groups. The mean age was slightly older in the HFNC group, although this difference did not reach statistical significance (64 vs. 60, $p=0.051$). A statistical difference was noted between the two groups in the number of pulmonary comorbidities ($p=0.003$) and the grading of the severity of hypoxemia ($p<0.001$). These may be related to the clinician's decision after comprehensive consideration. The more comorbidities the more likely to affect lung function as well as the easier it is for HFNC to maintain oxygenation in patients with moderate to severe, especially severe hypoxemia.

Vital signs and FiO_2 are recorded before and after bronchoscopy (Table 2). No significant differences were observed in oxygen saturation and heart rate between the two groups before and after FOB. Systolic blood pressure (126 vs. 118 mmHg, $p<0.001$; 126 vs. 121 mmHg, $p=0.022$) and FiO_2 (45.9% vs. 35.9%; 45.2% vs. 37.4%, $p<0.001$) were higher in the HFNC group than in the COT group throughout the procedure. Although the mean arterial pressure (MAP) in the HFNC group was significantly higher than that in the COT group before the operation (90 vs. 87 mmHg, $p=0.019$), there was no statistical significance between the two groups after the operation (91 vs. 89 mmHg, $p=0.157$).

The parameters before and after the procedure are analysed separately in both groups (Fig. 2). Vital signs fluctuated significantly during bronchoscopy in the COT group, and their systolic blood pressure, MAP, heart rate, flow rate, and FiO_2 were significantly elevated. Blood pressure remained stable throughout the FOB in the HFNC group, but the heart rate was significantly higher

Table 1 Characteristics of the patients at baseline

Parameters	HFNC ($n=78$)	COT ($n=154$)	p value
Male Gender	61(78.2%)	112(72.7%)	0.365
Age, years	64 ± 12	60 ± 13	0.051
BMI	21.4 ± 3.3	21.8 ± 3.3	0.441
Current or past smoking	27(34.6%)	61(39.6%)	0.459
Number of pulmonary complications 0.003			
0	39(50%)	49(31.8%)	0.007
1	20(25.6%)	74(48.1%)	0.001
≥ 2	19(24.4%)	31(20.1%)	0.459
Indication for bronchoscopy			0.084
Pneumonia	58(74.4%)	86(55.8%)	0.008
COPD/asthma	4(5.1%)	17(11.0%)	0.221
ILD	9(11.5%)	23(14.9%)	0.550
Lung cancer	5(6.4%)	19(12.3%)	0.180
Bronchiectasis	2(2.6%)	9(5.8%)	0.343
Types of bronchoscopy			0.176
BAL	54(69.2%)	93(60.4%)	0.187
BAL + Bronchial brushing	15(19.2%)	30(19.5%)	0.964
Inspection only	6(7.7%)	9(5.8%)	0.583
TBLB	2(2.6%)	18(11.7%)	0.024
EBUS + TBNA	1(1.3%)	4(2.6%)	0.666
Severity of hypoxemia			< 0.001
Mild (200 < PF ratio ≤ 300 mmHg)	37(47.4%)	113(73.4%)	< 0.001
Moderate (100 < PF ratio ≤ 200 mmHg)	35(44.9%)	40(26.0%)	0.004
Severe (PF ratio ≤ 100 mmHg)	6(7.7%)	1(0.6%)	0.006

Table 2 Mean differences in physiologic parameters before and after bronchoscopy procedures

Parameters	HFNC ($n=78$)	COT ($n=154$)	p value
Before bronchoscopy			
Arterial pressure(mmHg)			
Systolic	126 ± 17	118 ± 14	< 0.001
MAP	90 ± 11	87 ± 10	0.019
Heart rate (beats/min)	91 ± 14	92 ± 16	0.618
FiO_2(%)	45.9 ± 17.9	35.9 ± 6.9	0.000
SpO_2(%)	94.9 ± 2.6	95.3 ± 2.4	0.220
After bronchoscopy			
Arterial pressure(mmHg)			
Systolic	126 ± 17	121 ± 15	0.022
MAP	91 ± 11	89 ± 11	0.157
Heart rate (beats/min)	94 ± 16	98 ± 17	0.051
FiO_2(%)	45.2 ± 17.4	37.4 ± 10.0	< 0.001
SpO_2(%)	94.7 ± 2.7	94.1 ± 5.0	0.315

than that before (94 vs. 91, $p=0.006$). Meanwhile, the mean FiO_2 in the HFNC group at the end of the procedure was 45.2%, which was lower than that in the preoperative period, but the difference was not statistically significant. And there was no significant change in the flow rate before and after. Although both groups exhibited a decrease in oxygen saturation after FOB compared with that before, only the COT group demonstrated a statistical difference (95.32% vs. 94.06%, $p=0.002$).

Clinical endpoints during bronchoscopy are shown in Table 3. The lowest SpO_2 during the procedure was 93.1%±4.6% in the HFNC and 92.6%±5.8% in the COT group ($p=0.555$). However, the occurrence of the lowest SpO_2 < 90% tended to be more frequent in the COT group (17.5% vs. 3.8%, $p=0.003$). No serious adverse events, including severe arrhythmia, sudden cardiac arrest, severe laryngeal oedema (laryngeal obstruction of the third degree or higher), or respiratory arrest, were observed in either group. A total of 37 patients suffered from general adverse events such as blood pressure fluctuations, tachycardia, bucking, and chest distress during the operation, with tachycardia (75.7%) being the most

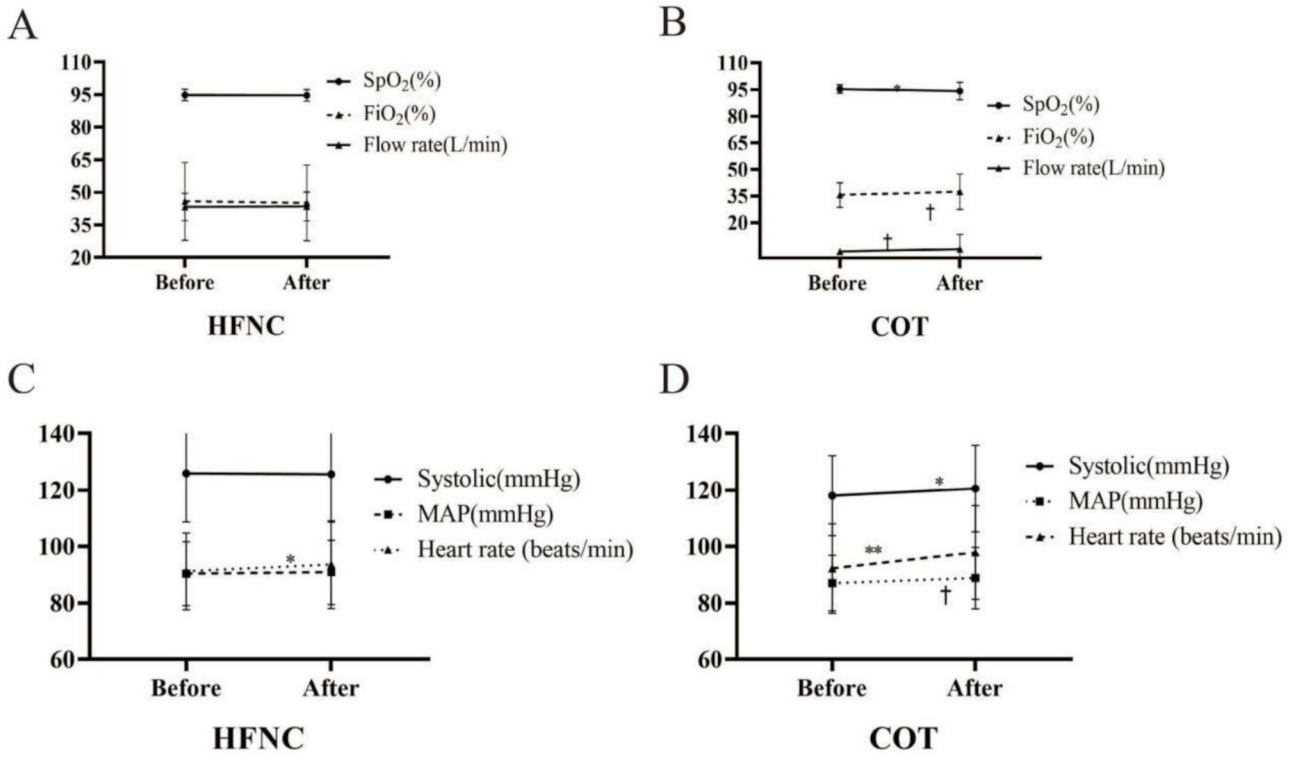

Fig. 2 Parameters before and after bronchoscopy in the two groups. (**A.C**) Changes in blood pressure, heart rate, oxygen saturation, flow rate, and fraction of inspired oxygen before and after operation in the HFNC group. (**B.D**) Changes in blood pressure, heart rate, oxygen saturation, flow rate, and fraction of inspired oxygen before and after operation in the COT group
*: $p<0.05$; †: $p<0.05$; **: $p<0.001$

Table 3 Primary and secondary outcomes during bronchoscopy

Outcomes	HFNC ($n=78$)	COT ($n=154$)	p value
The lowest SpO_2<90%	3(3.8%)	27(17.5%)	0.003
The lowest SpO_2 (%)	93.1 ± 4.6	92.6 ± 5.8	0.555
General adverse events	6(7.7%)	31(20.1%)	
Elevated blood pressure	0(0.0%)	2(1.3%)	0.015
Blood pressure drop	0(0.0%)	1(0.6%)	-
Tachycardia	6(7.7%)	22(14.3%)	-
Bucking	1(1.3%)	3(1.9%)	-
Chest distress	0(0.0%)	3(1.9%)	-
Operation interrupt	0(0.0%)	9(5.8%)	0.069
Escalation of Oxygen therapy	0(0.0%)	9(5.8%)	0.069

common general adverse event. The overall incidence of such events was significantly higher in the COT group (20.1% vs. 7.7%, $p=0.015$). Nine (5.8%) patients in the COT group experienced operational interruptions, and nine (5.8%) patients had their respiratory support modality upgraded to an oxygen mask or HFNC although it did not reach statistical significance between the two groups ($p=0.069$). However, no patients in the HFNC group experienced operational interruptions or required an upgrade to their oxygen therapy modality.

Indicators that were statistically significant or potentially clinically significant in the univariate analysis were included as independent variables in the multivariate binomial logistic regression analysis, with the occurrence of deoxygenation events as the dependent variable. The analysis showed that the use of HFNC was a protective factor during the operation ($p=0.002$, odds ratio [OR]=0.117, 95% confidence interval [CI]: 0.030–0.449) (Table 4). The P/F ratio was also identified as a protective factor influencing the occurrence of deoxygenation events during operation ($p=0.032$, OR=0.990, 95% CI: 0.982–0.999). This suggests that patients with more severe hypoxemia are more likely to experience deoxygenation during the procedure.

We divided hypoxemic patients into mild ($n=150$, 200<P/F ratio≤300 mmHg) and moderate-to-severe ($n=82$, P/F ratio≤200 mmHg) groups. The subgroup analysis showed that for patients with mild hypoxemia, there was no significant difference between the two modes of respiratory support during FOB in terms of reduction of desaturation events (HFNC: 5.4% vs. COT: 14.2%, $p=0.258$) and general adverse events (HFNC: 8.1% vs. COT: 16.8%, $p=0.194$) (Table 5). In contrast, for moderate-to-severe patients, the incidence of deoxygenation events was significantly lower in the HFNC group (2.4% vs. 26.8%, $p=0.002$), and the COT group had a significantly higher rate of general adverse events (29.3% vs. 7.3%, $p=0.01$).

Table 4 Factors associated with desaturation events during bronchoscopy in hypoxemic patients

Variable	β coefficient	Standard error	Odds ratios (95% CI)	*p* value
Oxygen therapy (COT*vs. HFNC)	-2.147	0.687	0.117 (0.030–0.449)	0.002
P/F ratio	-0.010	0.005	0.990 (0.982–0.999)	0.032
Number of pulmonary complications				
0	Reference			
1	0.071	0.570	1.073 (0.351–3.279)	0.901
≥ 2	0.370	0.667	1.448 (0.392–5.354)	0.579
Indication for bronchoscopy				
Pneumonia	Reference			
ILD	1.059	0.603	2.884 (0.884–9.404)	0.079
COPD/asthma	-1.548	1.136	0.213 (0.023–1.969)	0.173
Lung cancer	0.748	0.756	2.113 (0.480–9.296)	0.322
Bronchiectasis	-19.872	11576.663	0.000	0.999
Types of bronchoscopy procedure				
BAL	Reference			
BAL + Bronchial brushing	0.043	0.556	1.044 (0.351–3.105)	0.939
Inspection only	0.246	0.878	1.278 (0.229–7.145)	0.780
TBLB	-0.728	0.786	0.483 (0.103–2.256)	0.355
EBUS + TBNA	-0.144	1.360	0.866 (0.060–12.454)	0.916

* COT is the reference

Table 5 Primary and secondary outcomes during bronchoscopy in the subgroup analysis

Parameters	HFNC	COT	*p* value
200 < P/F ratio ≤ 300 mmHg			
The lowest SpO_2<90%	2(5.4%)	16(14.2%)	0.258
General adverse events	3(8.1%)	19(16.8%)	0.194
P/F ratio ≤ 200 mmHg			
The lowest SpO_2<90%	1(2.4%)	11(26.8%)	0.002
General adverse events	3(7.3%)	12(29.3%)	0.01

Primary and secondary outcomes during bronchoscopy in the subgroup analysis. Although no significant difference was observed in outcome events between the HFNC and COT groups in the mild hypoxemia population, the COT group experienced a statistically significant increase in heart rate (97 vs. 91, $p<0.001$), mean arterial pressure (89 vs. 86, $p=0.005$), and a decrease in oxygen saturation (94.6 vs. 95.6, $p=0.002$) (table 6). In contrast, the HFNC group did not show any statistically significant changes in pre- and post-operative vital signs.

Discussion

In this study, we found that HFNC significantly prevented the occurrence of deoxygenation events during FOB and reduced the incidence of general adverse events, such as fluctuations in blood pressure and heart rate, as well as intraoperative bucking. Compared with nasal cannula oxygenation, HFNC facilitated the operation to a certain extent. This result is similar to what we observed in our clinical operations and is largely in line with our hypothesis. Although a significant increase was observed in the heart rate at the end of FOB, regardless of the use of HFNC or nasal cannula oxygen, it seems more likely that this was due to secondary sympathetic hyperactivity induced by stressful situations. However, advantages such as the comfort of the HFNC compared to the COT group and its ability to provide a more consistent oxygen demand reduced patient anxiety, which may account for the less tachycardia in the mild hypoxemic HFNC group. Additionally, the multifactorial analysis showed that the P/F ratio was a protective factor for the occurrence of desaturation events ($p=0.032$, OR = 0.990, 95% CI: 0.982–0.999). Patients with higher levels of hypoxemia were more likely to experience a deoxygenation event. In the subgroup analysis, we found that in patients with mild hypoxemia, although there was no significant difference between HFNC and nasal cannula oxygenation in terms of the primary outcome event, patients who received HFNC had smoother changes in vital signs, such as heart rate, blood pressure, and oxygen saturation, throughout the procedure. Therefore, considering economic factors,

Table 6 Physiologic parameters before and after bronchoscopy procedures in patients with mild hypoxemia

Parameters	HFNC			COT		
	Before	After	*P* value	Before	After	*p* value
MAP (mmHg)	92 ± 9	92 ± 11	0.684	86 ± 10	89 ± 11	0.005
Heart rate (beats/min)	92 ± 12	93 ± 15	0.136	91 ± 17	97 ± 17	<0.001
SpO_2(%)	95.2 ± 2.6	95.3 ± 2.9	0.701	95.6 ± 2.4	94.6 ± 3.5	0.002

the choice of respiratory support for patients with mild hypoxemia can be evaluated from multiple perspectives. Nevertheless, it is undeniable that patients in the COT group were still more susceptible to experiencing deoxygenation events during maneuvers despite lower baseline pulmonary comorbidities and hypoxia. However, for patients with moderate-to-severe hypoxemia, we recommend the use of HFNC as a form of respiratory support during FOB, as it offers a higher degree of safety and utility.

We found that the oxygen saturation before and after the operation in COT group was statistically significant (95.32% vs. 94.06%, $p=0.002$) and that the 1% difference, although numerically meaningful, was not of particular value for clinical purposes. Therefore, we did not have this as a primary outcome indicator for both respiratory therapies. Regardless, the COT group did appear to be more likely to have $SpO_2<90\%$. Since appropriate local anesthesia already ensured comfort for most patients, we excluded patients for whom general anesthesia was used during the operation. Although sedation is often used during FOB, it may alter breathing patterns and even carry the risk of causing severe respiratory depression [14–16]. By avoiding sedation in the study, we excluded confounding factor which might affect gas exchange.

To date, there have been few studies on HFNC in FOB, especially in hypoxemic patients. A small study conducted on five patients found that the use of HFNC during BAL could reduce the FiO_2 value at 30 min postoperatively to varying degrees [17]. Similarly, our study also showed comparable results, with a reduction in inhaled oxygen concentrations in the HFNC group at the end of the operation compared with the initial values, although the difference did not reach statistically significance. Another retrospective analysis showed that in patients with mild hypoxemia, there were no significant differences in deoxygenation events, hypotensive events, and endotracheal intubation rates in the HFNC group relative to the COT group [18]. Although this is consistent with the results of our subgroup analysis, the COT in that study was not limited to nasal cannula oxygenation alone. Therefore, it is not possible to determine whether there is a difference between HFNC and nasal cannula oxygenation alone. Longhini F et al. stated that HFNC provides better oxygenation to COT, but this was primarily for outpatients and has not been evidenced further for hypoxemic patients [9]. Similarly, wang et al. concluded that HFNC reduces the proportion of patients with deoxygenation events during FOB, but they excluded patients with $SpO_2<90\%$ [13]. Of course, HFNC also has advantages in some patients with specific diseases [19]. Interestingly, a randomized controlled trial found that compared to COT, HFNC did not reduce the proportion of patients experiencing desaturation during EBUS. This may be related to the presence of hypercapnia in the participants [20]. Additionally, most studies have opted to perform bronchoscopy via the oral route, which may negate the advantage of continuous positive airway pressure provided by HFNC. Bronchoscopy performed through the nasal route can minimize the loss of that advantage due to the route of manipulation.

This study has a few limitations. First, being a retrospective, single-centre study, it has the inherent drawback of selection bias, as well as the inability to provide a larger patient's sample size. Second, due to the small sample size of patients with severe hypoxemia, in the subgroup analysis, we chose a P/F ratio ≤ 200 as the critical value and redivided the patients into two subgroups, mild and moderately severe. Nonetheless, our findings still demonstrate the superiority of HFNC in reducing the risk of desaturation and ensuring operational stability. Third, due to the retrospective design and incomplete data collection, we primarily relied on SpO_2, a simple and no-invasive measurement, as the main parameter of our study. However, we were unable to analyse other parameters, including pulmonary ventilation function, arterial partial pressure of oxygen, and arterial partial pressure of carbon dioxide. In addition, we can only use a simple formula to derive the FiO_2 for nasal cannula oxygen. Since the FiO_2 should theoretically be equal to the ratio of pure oxygen inhaled per unit of time to the tidal volume, this formula is more in line with the ideal breathing pattern of a normal person. In a non-ideal pattern, the FiO_2 is affected by the patient's tidal volume, respiratory rate, and respiratory cycle [21], and thus, our results may be less accurate.

Conclusions

Our findings suggest that HFNC can reduce the incidence of $SpO_2<90\%$ during FOB in patients with hypoxemia and significantly reduce the occurrence of adverse events, especially in those with moderate-to-severe hypoxemia. For all hypoxemic patients undergoing bronchoscopy, the advantages of HFNC in maintaining operational stability during bronchoscopy should not be ignored. In patients with underlying medical conditions, such as high blood pressure, HFNC is a preferred form of respiratory support, even if the degree of hypoxemia is mild, which may make the procedure smoother and less risky. In future studies, whether extrapulmonary complications can affect the advantage of HFNC in maintaining operational stability during bronchoscopy is worthy of further discussion and verification.

Abbreviations

ARF	Acute respiratory failure
BAL	Bronchoalveolar lavage
BMI	Body mass index
COT	Conventional oxygen therapy

COPD	Chronic obstructive pulmonary diseases
CI	Confidence Interval
EBUS-TBNA	Endobronchial ultrasound-guided trans-bronchial needle aspiration
FOB	Fiberoptic bronchoscopy
FiO_2	Fraction of inspired oxygen
HFNC	High-flow nasal cannula
ILD	Interstitial lung disease
MAP	Mean arterial pressure
OR	Odds Ratio
PaO_2	Arterial partial pressure of oxygen
$PaCO_2$	Arterial partial pressure of carbon dioxide
TBLB	Transbronchial lung biopsy

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Author contributions
XL and FX carried out the research design and conception; XL analyzed and interpreted the data regarding; XL and FX wrote and revised the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets generated and analyzed during the current study are not publicly available due [PROTECT PATIENT PRIVACY] but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This was a retrospective, observational, single-center study, which was approved by the Ethics Committee of Union Hospital of Tongji Medical College, Huazhong University of Science and Technology (No. 816 of 2023). The need for written informed consent was waived by the Union Hospital of Tongji Medical College, Huazhong University of Science and Technology ethics committee due to the retrospective nature of the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Payne CB Jr, Goyal PC, Gupta SC. Effects of Transoral and Transnasal Fiberoptic Bronchoscopy on Oxygenation and Cardiac Rhythm. Endoscopy. 1986;18:1–3.
2. Grensemann J, Simon M, Wachs C, Kluge S. [High-flow oxygen therapy-chances and risks]. Pneumologe (Berl). 2022;19(1):21–6.
3. Mauri T, Turrini C, Eronia N, Grasselli G, Volta CA, Bellani G, Pesenti A. Physiologic effects of High-Flow Nasal Cannula in Acute Hypoxemic Respiratory failure. Am J Respir Crit Care Med. 2017;195(9):1207–15.
4. Parke RL, Eccleston ML, McGuinness SP. The effects of flow on airway pressure during nasal high-flow oxygen therapy. Respir Care. 2011;56(8):1151–5.
5. Rochwerg B, Granton D, Wang DX, Helviz Y, Einav S, Frat JP, Mekontso-Dessap A, Schreiber A, Azoulay E, Mercat A, et al. High flow nasal cannula compared with conventional oxygen therapy for acute hypoxemic respiratory failure: a systematic review and meta-analysis. Intensive Care Med. 2019;45(5):563–72.
6. Oczkowski S, Ergan B, Bos L, Chatwin M, Ferrer M, Gregoretti C, Heunks L, Frat JP, Longhini F, Nava S et al. ERS clinical practice guidelines: high-flow nasal cannula in acute respiratory failure. Eur Respir J 2022, 59(4).
7. Haustraete E, Obert J, Diab S, Abbes S, Zini JM, Valade S, Lerolle N, Albin N, Arnulf B, Bouaziz JD, et al. Idelalisib-related pneumonitis. Eur Respir J. 2016;47(4):1280–3.
8. Service JA, Bain JS, Gardner CP, McNarry AF. Prospective experience of high-flow nasal oxygen during bronchoscopy in 182 patients: a feasibility study. J Bronchol Interv Pulmonol. 2019;26(1):66–70.
9. Longhini F, Pelaia C, Garofalo E, Bruni A, Placida R, Iaquinta C, Arrighi E, Perri G, Procopio G, Cancelliere A, et al. High-flow nasal cannula oxygen therapy for outpatients undergoing flexible bronchoscopy: a randomised controlled trial. Thorax. 2022;77(1):58–64.
10. Irfan M, Ahmed M, Breen D. Assessment of High Flow Nasal Cannula Oxygenation in Endobronchial Ultrasound Bronchoscopy. J Bronchol Interventional Pulmonol. 2021;28(2):130–7.
11. Zhang W, Wang J-L, Fu S, Zhou J-M, Zhu Y-J, Cai S-N, Fang J, Xie K-J, Chen X-Z. Incidence of oxygen desaturation using a high-flow nasal cannula versus a facemask during flexible bronchoscopy in patients at risk of hypoxemia: a randomised controlled trial. BMC Pulm Med 2022, 22(1).
12. Simon M, Braune S, Frings D, Wiontzek A-K, Klose H, Kluge S. High-flow nasal cannula oxygen versus non-invasive ventilation in patients with acute hypoxaemic respiratory failure undergoing flexible bronchoscopy - a prospective randomised trial. Crit Care 2014, 18(6).
13. Wang R, Li HC, Li XY, Tang X, Chu HW, Yuan X, Tong ZH, Sun B. Modified high-flow nasal cannula oxygen therapy versus conventional oxygen therapy in patients undergoing bronchoscopy: a randomized clinical trial. BMC Pulm Med. 2021;21(1):367.
14. Costa R, Navalesi P, Cammarota G, Longhini F, Spinazzola G, Cipriani F, Ferrone G, Festa O, Antonelli M, Conti G. Remifentanil effects on respiratory drive and timing during pressure support ventilation and neurally adjusted ventilatory assist. Respir Physiol Neurobiol. 2017;244:10–6.
15. Vaschetto R, Cammarota G, Colombo D, Longhini F, Grossi F, Giovanniello A, Della Corte F, Navalesi P. Effects of propofol on patient-ventilator synchrony and interaction during pressure support ventilation and neurally adjusted ventilatory assist. Crit Care Med. 2014;42(1):74–82.
16. Wang L, Wu Q, Wang M, Ming W, Sheng C, Zhang Y, Chen Y, Cao Y. The safety and efficacy of alfentanil combined with midazolam in fiberoptic bronchoscopy sedation: a randomized, double-blind, controlled trial. Front Pharmacol. 2022;13:1036840.
17. Miyagi K, Haranaga S, Higa F, Tateyama M, Fujita J. Implementation of bronchoalveolar lavage using a high-flow nasal cannula in five cases of acute respiratory failure. Respiratory Invest. 2014;52(5):310–4.
18. Kim EJ, Jung CY, Kim KC. Effectiveness and safety of High-Flow Nasal Cannula Oxygen Delivery during Bronchoalveolar Lavage in Acute Respiratory failure patients. Tuberc Respir Dis 2018, 81(4).
19. Sharma VK, Singh PK, Govindagoudar MB, Thulasi A, Chaudhry D, Shriram CP, Lalwani LK, Ahuja A. Efficacy of different respiratory supports to prevent hypoxia during flexible bronchoscopy in patients of COPD: a triple-arm, randomised controlled trial. BMJ Open Respir Res 2023, 10(1).
20. Douglas N, Ng I, Nazeem F, Lee K, Mezzavia P, Krieser R, Steinfort D, Irving L, Segal R. A randomised controlled trial comparing high-flow nasal oxygen with standard management for conscious sedation during bronchoscopy. Anaesthesia. 2018;73(2):169–76.
21. O'Reilly Nugent A, Kelly PT, Stanton J, Swanney MP, Graham B, Beckert L. Measurement of oxygen concentration delivered via nasal cannulae by tracheal sampling. Respirology. 2014;19(4):538–43.

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