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Article

The Role of High-Flow Nasal Cannula (HFNC) During Flexible Bronchoscopy in Adult Patients with Moderate Respiratory Dysfunctions: An Observational Study

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Abstract

Background/Objectives: Flexible bronchoscopy (FB) enables airway exploration and diagnosis of various respiratory pathologies, but the sedation and instrumentation required during the procedure raise oxygen demand while reducing ventilation, which can lead to hypoxemia. Conventional oxygen therapy (COT) may not adequately prevent desaturations in high-risk groups, as patients with moderate respiratory deficiency. High-flow nasal cannula (HFNC) can deliver heated, humidified oxygen at high flow rates, generating low-level positive airway pressure, improving oxygenation, reducing dead-space and enhancing procedure tolerance. Prior studies have shown that HFNC can improve gas exchange and reduce desaturations during bronchoscopy. However, evidence remains limited for patients with moderate respiratory deficiency, who are particularly vulnerable. Evaluating feasibility and safety of HFNC in this population is essential to guide safe procedural practice. **Methods:** Prospective observational study including patients undergoing FB with HFNC support between January and May 2025. Inclusion criteria were BMI between 18 to 30; age >18 years old; moderate respiratory dysfunction, defined by pulse oximetry, Pulmonary Functional Tests (PFTs) and Arterial Blood Gas (ABG) analysis. Exclusion criteria were intolerance/contraindication to HFNC. Procedures were performed under basic monitoring. Primary outcome was occurrence of severe hypoxemia (spO₂ <90%). Secondary outcomes were need for rescue maneuvers, interruption for conversion to other ventilatory strategies, hemodynamic instability. **Results:** No severe desaturations were recorded, and all procedures were completed without rescue maneuvers or other ventilatory strategies; no hypotensive have occurred. Mean duration of the procedure was 9 minutes. Vital parameters were maintained into the normal ranges, with a mean SpO₂ during bronchoscopy of 98%. **Conclusions:** HFNC enables oxygenation and ventilation without adverse events in sedations for FB in patients with moderate respiratory deficiency.

Keywords: ICU; flexible bronchoscopy; HFNC; respiratory failure

1. Introduction

Flexible bronchoscopy (FB) involves the insertion of a flexible, fiber-optic bronchoscope through the oral or nasal route for direct visualization of the tracheobronchial tree. It has long been established as an essential diagnostic and therapeutic tool in respiratory medicine and critical care, allowing

inspection of the airways and diagnosis of various respiratory pathologies, enabling collection of bronchial brushings, bronchoalveolar lavage (BAL), and tissue biopsies. Furthermore, it enables direct intervention for airway stenting, secretion removal, or foreign body retrieval [1]. Given the potential for discomfort, cough reflex activation, and procedural anxiety, sedation is generally required to enhance patient tolerance, facilitate procedural success, and ensure safety. Sedative agents such as propofol or midazolam, are commonly utilized to achieve an appropriate depth of sedation, while maintaining spontaneous ventilation whenever possible [2,3].

FB is associated with a spectrum of potential complications, notably respiratory and hemodynamic disturbances. Among these, hypoxemia is particularly prevalent, with reported incidences ranging from 30% to 70%, and is often accompanied by a reduction in arterial oxygen tension (PaO₂) of approximately 20 mmHg, especially during BAL, when large volumes of fluid are instilled into the distal airways [4]. Other commonly observed adverse events include cough, bronchospasm, dyspnea [5], hypercapnia, blood pressure fluctuations, and arrhythmias [6] directly correlated to the level of hypoxia [7]. These complications are particularly significant in patients with underlying pulmonary disease or compromised respiratory function, where even brief episodes of hypoxemia can precipitate clinical deterioration.

Several studies highlighted the need for supplemental oxygen administration during FB [8,9] yet the optimal delivery method remains a subject of debate.

Conventional oxygen therapy (COT) via nasal cannulas or face masks is often used for maintaining oxygenation during FB. However, COT is less efficient in patients with moderate to severe respiratory impairment. The low flow rates achievable with COT may be insufficient to maintain adequate oxygenation in the presence of hypoventilation induced by sedative medications, pre-existing pulmonary dysfunction, or prolonged procedural duration. Additionally, shared airway between the bronchoscopist and the responsible for ventilatory support hinders adequate delivery of supplemental oxygen and may limit the ability to timely correct hypoxemia [10,11].

Non-invasive ventilation (NIV) can overcome some of the limitations of COT. Several studies have demonstrated that NIV can reduce the frequency and severity of desaturation during FB, maintain adequate gas exchange, and decrease the need for post-procedure invasive ventilatory support. NIV has been particularly effective in patients with significant hypoxemia or respiratory compromise, not only in maintaining ventilation, but also conferring greater hemodynamic stability during procedures [12]. The British Thoracic Society and other international guidelines recommend the use of NIV in hypoxemic patients undergoing FB in settings where facilities for emergent intubation and advanced ventilatory support are immediately available [13]. However, NIV is rarely used because of patients' intolerance and difficulty advancing the bronchoscope through the nares, and patient-ventilator asynchrony can occur, adding to discomfort and complicating procedure.

High-flow nasal cannula (HFNC) has recently emerged as a novel solution for non-invasive oxygen delivery, offering several physiological advantages over both COT and NIV. HFNC delivers heated and humidified oxygen at high flow rates, allowing for the administration of higher inspired oxygen fractions, generation of low levels of positive airway pressure, reduction of anatomical dead space, and restoration of functional residual capacity, thereby improving ventilation-perfusion (V/Q) matching and overall oxygenation [14,15]. In addition, HFNC enhances mucociliary clearance, reduces airway resistance and bronchoconstriction, and is generally well tolerated by patients, even during prolonged procedures [16]. These properties make HFNC a particularly attractive option for patients with moderate respiratory dysfunction, in whom the risks of hypoxemia and hypercapnia are increased [17,18].

Several studies have evaluated the role of HFNC in maintaining adequate oxygenation and ventilation during bronchoscopic procedures, demonstrating a reduction in incidence of procedure-related desaturation, minimized need for endotracheal intubation, and enhanced patient comfort compared to conventional oxygen therapy [19–23]. Available research is still sparse on the use of HFNC specifically in patients with moderate respiratory dysfunction—a population that is

particularly vulnerable to procedural complications yet may benefit most from optimized non-invasive oxygen delivery strategies.

Given this context, the present study aims to assess the feasibility, safety, and clinical impact of HFNC in patients with moderate respiratory impairment undergoing FB. Specifically, we sought to evaluate respiratory and hemodynamic parameters, sedation tolerance, and the incidence of procedure-related adverse events, with the overarching goal of determining whether HFNC can serve as a reliable and effective oxygenation strategy in this high-risk patient population. By providing detailed clinical observations, this study aims to contribute to the growing body of evidence supporting the use of HFNC as a safe and efficacious modality for respiratory support during invasive airway procedures.

2. Materials and Methods

Between January and May 2025, a prospective observational study was initiated at a single center following introduction of HFNC into practice according to the institutional protocol.

Inclusion criteria were: age above 18 years old, a BMI between 18 and 30. Inclusion also required having moderate respiratory dysfunction, defined by either pre-procedural pulse oximetry demonstrating spO_2 between 92 and 88% and/or Arterial Blood Gas (ABG) analysis showing paO_2 between 60-70 mmHg and/or pCO_2 between 45-55 mmHg with P:F between 100 and 200; Pulmonary Functional Tests (PFTs) resulting in either FEV_1 50-70% predicted, FVC 50-80% predicted, DLCO with 40-60% reduction. Exclusion criteria were poor tolerance or contraindication to HFNC, i.e. recent history of facial trauma or esophageal surgery; need for mechanical ventilation.

During the procedure patients were placed under continuous monitoring of blood pressure, 3-lead ECG, spO_2 , and $ETCO_2$. Patients were sedated with midazolam and/or propofol to maintain a Richmond Agitation Sedation Scale (RASS) score of -2/-3 with spontaneous breathing.

Data collected included: patients demographics (age, sex, BMI); PFTs; preprocedural parameters: spO_2 , pO_2 and pCO_2 from ABGs; procedure duration; hemodynamic parameters, cumulative dosage of sedatives.

All patients received HFNC (Fisher & Paykel Healthcare AIRVO 3) oxygen support with FiO_2 between 40 to 60% at 60 L/min to maintain spO_2 levels above 92%.

The primary outcome of the study was incidence of severe hypoxemic events, indicated by reduction in spO_2 below 90%. Secondary outcomes were need for rescue maneuvers, as jaw thrust and chin lift; conversion to other ventilatory support, as endotracheal tube placement for mechanical ventilation; procedural interruption.

3. Results

Twenty patients were included in the study (Table 1).

Table 1. Demographic and Clinical Characteristics of Patients (n = 20).

	Mean \pm SD/n (%)	Range
Age (years)	67.0 \pm 8	56 – 82
Sex (M/F)	9 (45%)/11 (55%)	–
BMI (kg/m ²)	25 \pm 3	20 – 30
Baseline SpO_2 (%)	94 \pm 3	88 – 97
PaO_2 (mmHg)	74 \pm 9	60 – 87
$PaCO_2$ (mmHg)	48 \pm 9	31 – 59
P/F ratio	162 \pm 19	136 – 200
FEV_1 (% predicted)	69 \pm 9	50 – 80
FVC (% predicted)	75 \pm 6	65 – 82
DLCO (% predicted)	66 \pm 14	40 – 85
BMI (kg/m ²)	25 \pm 3	20 – 30

Baseline SpO₂ (%)	94 ± 3	88 – 97
PaO₂ (mmHg)	74 ± 9	60 – 87

Age ranged between 56 and 82 years old, and the average BMI was 24.6 kg/m². Concerning baseline pulmonary functional characteristics, the mean spO₂ was 94% (ranging from 88 to 97%) and average P:F ratio was 162.

A summary of procedural findings and the outcome studied is shown in Table 2.

Table 2. Procedural Characteristics During FB with HFNC Support (n = 20).

	Mean ± SD/n (%)	Range
Duration of FB (min)	9 ± 2	6 – 13
Flow (L/min)	53 ± 9 *	40 – 60
Total midazolam dose (mg)	3.0 ± 0.8	2 – 5
Total propofol dose (mg)	8.5 ± 9.3	0 – 20
Occurrence of desaturation (SpO₂ < 90%)	0 (0%)	–
Highest SpO₂ during FB (%)	99.9 ± 0.4	99 – 100
Lowest SpO₂ during FB (%)	98.6 ± 0.8	97 – 99
Procedural interruption	0 (0%)	–
Conversion to invasive ventilation	0 (0%)	–
Jaw thrust/chin lift required	0 (0%)	–
Severe hypotension	0 (0%)	–

* median 60.

The mean duration of the procedure was 9-minute (range 6-13). Concerning the HFNC flow settings, average flow applied was 53 L/min (median 60 L/min). Sedative medications used during FB were midazolam and propofol, with cumulative dosage on average of 3 mg and 9 mg, respectively.

Concerning the primary outcome of the study, none of the patient has experienced severe desaturations, the lowest value of spO₂ recorded being 97% in 3 out of 20 patients, each having preprocedural spO₂ below 92%.

As for the secondary outcome, none of the patients needed rescue maneuvers nor invasive ventilation, and no episodes of severe hypotension were documented.

4. Discussion

This study provides insights on the safety and feasibility of HFNC in patients with moderate respiratory deficiency undergoing FB. The mean procedural duration was approximately 9 minutes, reflecting efficient execution within standard clinical practice. Sedation protocols using low to moderate doses of midazolam and propofol allowed maintenance of adequate sedation levels while preserving spontaneous ventilation, as evidenced by the absence of any desaturation episodes (SpO₂ < 90%) during all procedures. Importantly, the highest and lowest oxygen saturation values remained stable and within safe limits. No patients required procedural interruption, escalation to invasive mechanical ventilation, or airway rescue maneuvers such as jaw thrust or chin lift. Additionally, there were no recorded episodes of severe hypotension, indicating hemodynamic stability throughout the procedures.

Current clinical practice guidelines recommend providing supplemental oxygen to prevent hypoxemia during flexible bronchoscopy. From a cost-benefit perspective, it is important to tailor respiratory support strategies to the patient's individual risk profile. Luo et al. [24] demonstrated that patients with mild hypoxemia and P:F ratios greater than 200 derived only limited benefit from HFNC compared with COT, whereas those with lower P:F ratios experienced a substantial reduction in hypoxemic events when managed with HFNC. These findings align with the results of Kaya et al. [25], who similarly identified a low P:F ratio as a risk factor for intraprocedural hypoxia. The authors

also suggested that varying indications for bronchoscopy may differentially influence the risk of procedural hypoxia, warranting further investigation.

In this context, some authors have questioned the routine use of oxygen supplementation in patients with only mild respiratory impairment, whereas others have shown that the risk of desaturation becomes significant primarily in individuals with markedly reduced FEV₁. [26]. More recently, Choi et al [27] screened a cohort of 2520 patients undergoing FB under sedation and found a significant association between procedural desaturations and age older than 60, low FEV₁ and duration over 40 minutes. In accordance to their findings, patients in our study were posed at greater risk for their age (average 67) and low FEV₁ (on average 69), while the average duration of 9 minutes might have represented a protective factor against hypoxemia. Smoother execution without interruptions and adequate level of sedation might have contributed to shorter duration, possibly relieving the cohort from the risk for hypoxia. Ben Menachem et al. [28] demonstrated how HFNC can dramatically reduce procedure duration, especially in high risk patients, as lung transplant receivers. Other authors [29,30] also demonstrated a lower rate of rescue interventions as jaw thrust and chin lift when comparing HFNC versus standard bag mask ventilation, in accordance with our results.

Despite positive results reported in several studies, the use of high-flow nasal cannula (HFNC) during flexible bronchoscopy (FB) still requires further investigation to optimize its implementation. Multiple studies have shown that HFNC reduces hypoxemic events in both diagnostic and therapeutic procedures. For example, Longhini et al. [31] evaluated HFNC during bronchoalveolar lavage in patients with suspected pneumonia and reported fewer hypoxemic episodes and a favorable safety profile. These findings emphasize the need to tailor oxygen therapy according to the severity and type of underlying lung disease when performing FB.

Supporting this, Roy et al. [32] conducted a systematic review and meta-analysis comparing HFNC with conventional oxygen therapy (COT) during bronchoscopy. HFNC was associated with higher SpO₂ nadirs, although no significant differences were observed in PaCO₂ levels before and after the procedure. The heterogeneity in pulmonary disease severity among study populations may influence CO₂ clearance and represents a potential source of bias [33].

The anatomical advantages of HFNC further facilitate bronchoscopy. Its nasal interface allows patients to keep their mouths mostly closed during the procedure, maintaining oxygen delivery, positive end-expiratory pressure, and CO₂ removal [34]. Historically, some authors have explored prophylactic or intraoperative insertion of nasopharyngeal tubes to manage hypoxia during FB [35,36]; while effective, invasive ventilation carries notable cardiovascular and respiratory risks and may not be justified for relatively short procedures.

NIV has also been used as an adjunctive support during FB in critically ill patients to prevent adverse events and reduce the need for endotracheal intubation [37]. NIV allows high mean airway pressures and inspiratory flows and simple triggering, which can facilitate bronchoscopy. However, concerns exist regarding side effects such as gastric distension [38] due to oral insertion of the bronchoscope and the increased risk of gas aspiration compared with HFNC. Saksitthichok et al. [39] reported greater post-procedural dyspnea with NIV, and Simon et al. [40] found that while NIV improved oxygenation compared to HFNC in patients with acute hypoxemic respiratory failure, it was also associated with higher reintubation rates within 24 hours. Notably, our study did not include a 24-hour follow-up period.

HFNC offers several advantages over NIV and COT, including ease of use, delivery of heated, humidified flows up to 60 L/min, and provision of end-expiratory positive pressure (~0.7 cm H₂O per 10 L/min) [41]. It effectively reduces hypoxemic episodes and lowers intubation requirements [42]. Compared with tight-fitting NIV masks, HFNC provides greater patient comfort, alleviates dyspnea, and can be applied in various clinical settings, including dedicated bronchoscopy suites [43]. Recent reviews indicate that HFNC outperforms COT in patients with moderate respiratory impairment, while NIV may be reserved for those with more severe acute respiratory failure [44].

Several studies have further examined the optimization of HFNC settings. Service et al. [45] reported that HFNC reduced desaturation rates and received positive feedback from clinicians, although optimal flow rates remain to be established. Lucangelo et al [46] compared Venturi Mask with HFNC at 40 and 60 L/min, demonstrating that higher flow rates improved outcomes, likely due to increased PEEP and airway patency. Similarly, Zhang and colleagues [47] identified an optimal flow of 50–60 L/min to prevent desaturations, consistent with the average flow used in our study (53 L/min).

While previous studies have yielded mixed evidence regarding the influence of comorbidities and baseline severity on bronchoscopy-related complications, with some authors reporting no association [27] and others highlighting substantial effects on desaturation rates [25], and post-procedural intubation, and overall complication burden, our ability to draw similarly robust conclusions is constrained by the methodological limitations of the present study. Specifically, the small sample size reduces statistical power and may obscure infrequent adverse events or subtle differences across patient subgroups. Additionally, the observational, single-center design introduces potential selection bias and limits generalizability. Heterogeneity in underlying respiratory conditions, sedation requirements, and indications for bronchoscopy further increases the risk of confounding, complicating efforts to disentangle the true impact of baseline patient characteristics on clinical outcomes [48].

Future study designs should accurately stratify patient populations with the scope of evaluating immediate procedural outcomes but also delayed complications and longer-term effects of HFNC. Additional research is needed to investigate in detail blood exchange dynamics in diverse patient populations undergoing bronchoscopic procedures, and larger scale studies to confirm these promising results.

5. Conclusions

HFNC can be a simple and effective strategy to support ventilation in patients with moderate respiratory dysfunction during FB, facilitating completion of the procedure without severe desaturations and other adverse events.

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Data Availability Statement: The corresponding author can provide databases and literature screening upon valid request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

FB	Flexible bronchoscopy
NIV	Noninvasive ventilation
HFNC	High-flow nasal cannula
PFT	Pulmonary Functional Tests

ABG	Arterial Blood Gas
BAL	Bronchoalveolar lavage
COT	Conventional oxygen therapy
RASS	Richmond Agitation Sedation Scale

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