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Evaluation of high flow nasal cannulae during endobronchial ultrasound bronchoscopy (EBUS) in high anaesthetic risk patients: a monocentric prospective study

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Abstract

Background EndoBronchial UltraSound-guided TransBronchial Needle Aspiration (EBUS-TBNA) is a widely used technique in pulmonary diseases. The procedure may lead to respiratory complications that affect patient's clinical status, especially in the presence of pre-existing comorbidities. The aim of this observational study is to investigate the effectiveness of oxygen therapy administered by high flow nasal cannulae (HFNC) in this setting.

Methods Study population comprised 40 consecutive patients with high anaesthetic risk (ASA III) who underwent EBUS-TBNA at the Tor Vergata University Hospital of Rome. 20 patients were oxygenated with standard low-flow system and 20 patients with HFNC. All patients underwent deep sedation with a combination of midazolam + propofol.

Results HFNC treated patients showed significant smaller drop in O_2 saturation compared to standard oxygen group (3.8 ± 5.9 vs 12.3 ± 15.3, 95% CI 0.91 to 16.14, $P = 0.029$). Furthermore, the lowest O_2 saturation in the control group was significantly lower (83.2 ± 15.6 vs 91.4 ± 5.9, 95% CI -15.86 to -0.35, $P = 0.041$) requiring a higher FiO_2 (oxygen fraction) increase compared to HFNC group (7.7 ± 9.7 vs 2.1 ± 6.3, 95% CI 26.16 to 66.84, P = 0.043). Episodes of desaturation were shorter in the HFNC group (90 ± 37.9 s. vs 120 ± 39.2 s., 95% CI 26.16 to 66.84, $P = 0.040$).

Conclusions Our results support HFNC as an effective tool to limit the severity of episodes of desaturation and hypoxia. The innovation of this work is represented by the use of HFNC in a population of complex patients at high anaesthetic risk.

Keywords HFNC, Sedation, EBUS-TBNA, Bronchoscopy, Anaesthetic risk

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Introduction

EndoBronchial UltraSound-guided TransBronchial Needle Aspiration (EBUS-TBNA) is a procedure indicated for the diagnosis, staging and typing of primary or metastatic tumors. It is also in our use for the diagnosis of granulomatous, cystic, infectious and haematological disorder of the mediastinum and of the lungs [1].

The anaesthetic approach adopted during EBUS-TBNA remains a subject of ongoing debate. The procedure can be performed under moderate or deep sedation, with the aim of ensuring maximum patient comfort throughout the examination [2, 3]. Deep sedation has proven to be a safe and effective strategy in terms of respiratory complications, both in younger and elderly patients [4]. General anaesthesia also represents a viable option; however, no significant differences have been observed compared to moderate sedation in terms of diagnostic yield or complication rates. On the contrary, moderate sedation has been associated with shorter procedure times and lower costs [5]. Similar findings have also been reported when comparing general anaesthesia with deep sedation, suggesting that the latter may serve as a valid alternative in settings where general anaesthesia is either unavailable or not indicated [6].

Given the procedure and the anaesthetic approach adopted, patients, often in older age and affected by multiple comorbidities, are exposed to various risks. In particular, older age, limited cardiopulmonary reserve, and pre-existing respiratory impairment are key factors predisposing to desaturation events [7]. Considering that repeated and prolonged episodes of desaturation are associated with an increased risk of serious peri-procedural cardiovascular events, ensuring adequate oxygenation throughout the procedure is of critical importance [8].

The strategy used for patient oxygenation, during sedation with spontaneous breathing, is often represented by the low-flow systems, such as nasal cannulas, which provide flows of up to 15 L/min with an inconsistent and variable oxygen fraction (FiO_2) that is influenced by patient's inspiratory demand [8]. In this context, oxygen desaturations (SpO_2 – Oxygen saturation < 90% For > 20 s) are frequent and are partly related to drugs used for sedation and partly to ventilation-perfusion mismatch caused by the procedure itself, especially in fragile patients with pre-existing comorbidities. The increase in airway resistance due to the presence of the fiberscope and the atelectasis phenomena could be responsible for impaired respiratory exchanges and lead to hypoxemia and the development of further related complications [7, 8, 10].

High flow nasal cannula (HFNC) oxygenation allows the administration of gas mixtures heated to temperatures between 31 and 37 °C and completely humidified, with flows of up to 60 L min −1, providing a constant oxygen fraction between 21 and 100% regardless of the flow. Therefore, in addition to facilitating secretion clearance, its ability to generate flow rates exceeding the patient's inspiratory demand minimizes the entrainment of ambient gases, thereby enhancing oxygenation [11–13]..

For critically ill patients, the use of nasal cannulae with high oxygen flow offers significant physiological advantages promoting carbon dioxide washout, reducing respiratory rate and work of breathing. Furthermore, generating a small positive pressure, it promotes alveolar distension increasing end-expiratory lung volume that correlates with functional residual capacity. It also prevent small airways closing, facilitate respiratory exchanges and improves oxygenation reducing pulmonary shunts [13, 14]. The increase in lung volume is favoured by the generation of an extrinsic positive expiratory pressure (PEEP) varying from 3 to 5 cmH_20, considered sufficient to recruit collapsed alveoli [15]. Recent studies have demonstrated that high-flow nasal cannula is an effective tool for oxygen supplementation during bronchoscopic procedures, showing superior results in preventing desaturation episodes and facilitating procedural performance for the operator compared to conventional oxygen therapy [16].

The use of HFNC has been described for almost a decade in the field of intensive care for patients with respiratory disorders and they have also been successfully used for various peri-operative manoeuvres such as pre-oxygenation and airway management, including difficult intubations [11].

In this work we compared the use of high-flow nasal cannula with traditional low-flow oxygen therapy systems, specifically nasal cannulae, for the oxygenation of patients with high anaesthetic risk (ASA III) undergoing EBUS-TBNA. The analysis focused primarily on the number and severity of desaturation episodes. The results suggest that HFNC is a safe and effective strategy for maintaining oxygenation during respiratory endoscopic procedures.

Materials and methods

Population

The study population consisted of 40 ASA III patients who underwent EBUS-TBNA at Tor Vergata University Hospital in Rome between April and September 2023. All participants provided written informed consent. The study protocol was approved by the Independent Ethics Committee of Policlinico Tor Vergata (PTV). Among them, 20 patients underwent EBUS-TBNA with standard low-flow oxygen delivered via nasal cannula (control group), while 20 patients underwent the procedure with HFNC (study group). The exclusion criteria for the study are as follows:

- Refusal to provide informed consent for anesthesia
- Pregnancy
- Age < 18 years
- Allergy or adverse reactions to propofol, midazolam, or flumazenil
- Procedure performed under emergency conditions
- Tolerance to hypnotic agents (e.g., substance abuse, including alcohol, benzodiazepines, or cannabis)
- Low to moderate anesthetic risk, classified as ASA I–II

Endpoints

The primary endpoints of the study is represented by the magnitude of respiratory depression-hypoxia episodes, defined as a reduction in O_2 saturation < 90% for more than 20 s, recorded through pulse oximetry [17].

Secondary endpoints include number and duration of desaturation episodes, increase in FiO_2 necessary to determine oxygen saturation to values above 90%, onset of hemodynamic alterations (SBP – Systolic blood pressure > 160 mmHg; DBP—diastolic blood pressure > 100 mmHg; SBP < 90 mmHg; DBP < 60 mmHg), arrhythmias, cough, hiccups, secretions, bronchospasm, need for intubation, procedure interruption, optimization of the anaesthetic plan for the safety of the procedure and patient comfort, procedure duration and discharge time.

Procedure

Both the study group and the control group underwent deep sedation in spontaneous breathing by administration of midazolam 0.06 mg/kg of body weight + propofol 0.5–1 mg/kg of body weight. Shortly before awakening, flumazenil 0.3–0.6 mg was administered [18]. During the procedure, patients were maintained under deep sedation corresponding to a RASS (Richmond Agitation-Sedation Scale) score of −4. For the examination, performed by expert pulmonologists, the patients were strictly placed in a semi-sitting position at 30° to ensure the maintenance of functional residual capacity (CFR). The procedure was performed via the oral route using a bite block. To the study group was administered oxygen with high flow nasal cannulas, with the Optiflow Thrive model system (Fisher & Paykel), using an interface appropriate to the patient, setting initial flows at 60 L/min and adjusting the FiO_2 to 50%. In the control group, oxygen therapy was guaranteed using nasal cannulae with low oxygen flow, with an initial flow rate of 4 L/min, subsequently adjusted according to the patient's needs (up to 15 L/min). In the event of desaturation (SpO_2 < 90% for more than 20 s), the FiO_2 was increased as needed in both groups, and manual jaw thrust maneuvers were performed. (Fig. 1). Patients were monitored with basic hemodynamic monitoring (oximetry, electrocardiogram, non-invasive pressure, respiratory rate), patient's breathing pattern was assessed and a scale assessing the patient's state of consciousness pre-, intra and post-procedure was applied

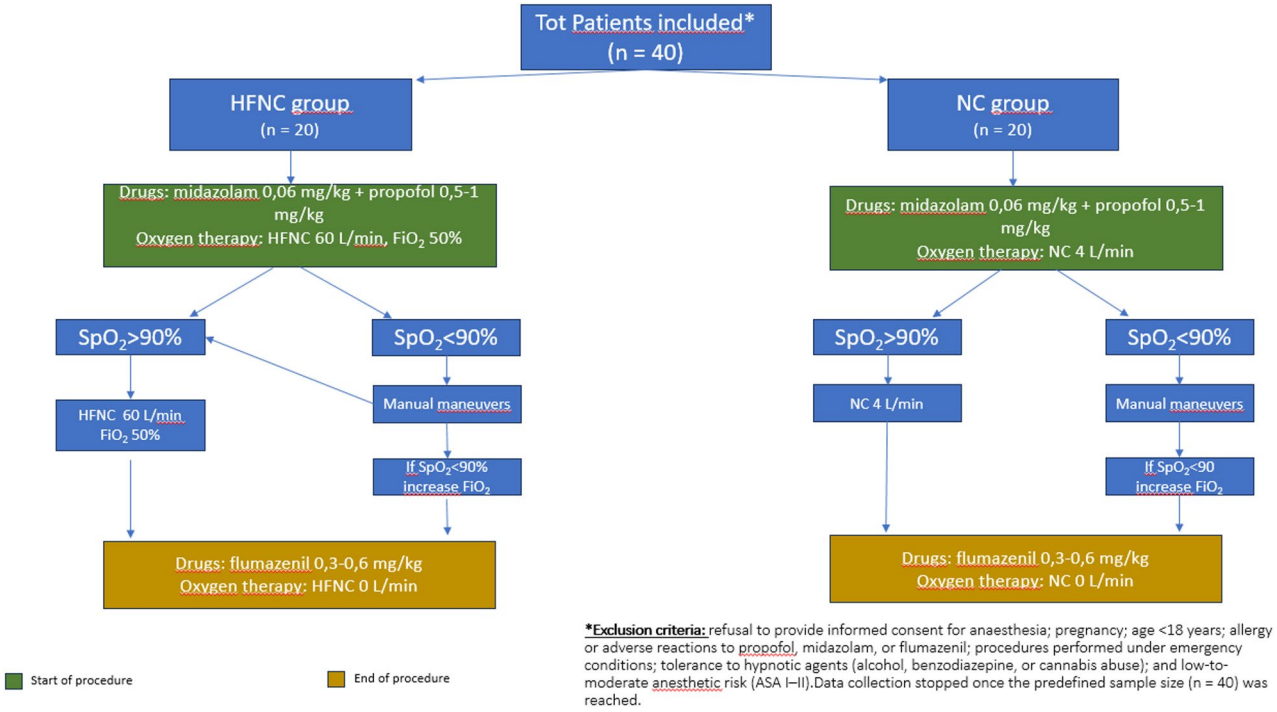

Fig. 1 Oxygenation approaches in the two groups considered

Table 1 Population demographic and clinical characteristics

	HFNC group (n 20)	NC group (n 20)	P
Male (%)	60%	70%	
Female (%)	40%	30%	
Age (aa)	67.2 ± 11.4	69.9 ± 10.1	*P* = 0.43
Weight (kg)	72.1 ± 16.9	72 ± 20	*P* = 0.95
Height (m)	1.67 ± 0.1	1.69 ± 0.1	*P* = 0.61
BMI	25.5 ± 4.7	25.1 ± 4.8	*P* = 0.79
ASA	3	3	
Cardiovascular desease	16 (80%)	18 (90%)	*P* = 0.66
Pulmunary desease	14 (70%)	14 (70%)	*P* > 0.99
Renal desease	1 (5%)	2 (10%)	*P* > 0.99
Metabolic desease	8 (40%)	4 (20%)	*P* = 0.30
Neurological desease	3 (15%)	1 (5%)	*P* = 0.60
Other deseases	8 (40%)	7 (35%)	*P* > 0.99

Table 2 Vital parameters at baseline and immediately after procedure

	HFNC group Mean ± DS	NC group Mean ± DS	P
Baseline T_0			
FiO_2	21 ± 0	22.3 ± 4.1	*P* > 0.99
SpO_2	95.1 ± 2.07	95.7 ± 1.9	*P* = 0.39
SBP	144.6 ± 25.0	140.5 ± 23.9	*P* = 0.60
DBP	80.5 ± 10.8	78.1 ± 9.6	*P* = 0.46
Heart rate	79.0 ± 13.9	79.8 ± 13.4	*P* = 0.85
RASS	0.1 ± 0.2	0	*P* > 0.99
Intraprocedural			
SpO_2	95.4 ± 4.9	93.7 ± 8.4	*P* = 0.05
SBP	132.2 ± 17.7	127.8 ± 21.0	*P* = 0.07
DBP	76.4 ± 10.8	74.0 ± 8.6	*P* = 0.07
Heart rate	85.5 ± 11.9	85.7 ± 14.0	*P* = 0.92
Respiratory rate	17.6 ± 4.4	17.5 ± 5.2	*P* = 0.83
RASS	−4	−4	*P* > 0.99
End of EBUS-TBNA			
FiO_2	21 ± 0	26.1 ± 11.3	*P* = 0.05
SpO_2	95.8 ± 1.5	95.7 ± 1.6	*P* = 0.76
SBP	136.5 ± 17.3	127.3 ± 19.6	*P* = 0.13
DBP	77.9 ± 9.4	75 ± 10.5	*P* = 0.36
Heart rate	81.7 ± 12.9	82.1 ± 15.3	*P* = 0.93
RASS	−0.1 ± 0.2	0	*P* > 0.99

(RASS) [19]. Measurements were assessed every 3 min. Furthermore, an accurate recording of the timing of drug administration and onset of action was carried out.

It should be noted that used drugs are already in use during endoscopic procedures, according to international protocols. The anaesthetic management was carried out by expert anaesthesiologists, according to clinical indications, as per current guidelines [18, 20].

Statistical analysis

All patients characteristics and variables were collected in a database created for the study. Data are presented as mean ± SD or percentages, as most appropriate. Comparisons between groups were evaluated by Student t test. For dichotomous nominal variables Fisher's exact test was applied. A P value < 0.05 was considered significant. GraphPad Prism version 10 (GraphPad software, Inc. La Jolla, USA) was used for statistical analysis and graphs.

Results

Overall 40 patients were enrolled in the study, divided into 2 groups. Twenty patients received oxygen through high-flow nasal cannulae with the Optiflow Thrive system. The second group received oxygen with use of traditional nasal cannulae. The groups were comparable in terms of demographic characteristics, with a slight male prevalence for both arms, and also comparable in terms of comorbidities (Table 1). All patients belong to class III of the ASA scale and were therefore considered to be at high anaesthetic risk.

No significant differences between study groups emerged for baseline oxygen saturation, fraction of oxygen delivered, hemodynamics, heart rate and level of consciousness assessed through observation and verbal and physical stimulation of the patient based on RASS scale (Table 2). The mean values of the intraprocedural parameters are presented in Table 2.

The drop in oxygen saturation during EBUS-TBNA was significantly smaller in HFNC group (3.8 ± 5.9 vs 12.3 ± 15.3, 95% CI 0.91 to 16.14, P = 0.029) (Fig. 2A); furthermore, the minimum SpO_2 value reached in the control group was significantly lower than in the HFNC group (83.2 ± 15.6 vs 91.4 ± 5.9, 95% CI −15.86 to −0.35, P = 0.041) (Fig. 2B). No statistically significant difference in terms of incidence of desaturation events between study groups was found, however the episodes themselves lasted for a significant shorter time in the HFNC group (90 ± 37.9 s. vs 120 ± 39.2 s., 95% CI 26.16 to 66.84, P = 0.040) (Table 3).

It should be noted that the control group needed an increase in the delivery of FiO2 significantly greater during hypoxic episodes than the experimental group (7.7 ± 9.7 vs 2.1 ± 6.3, 95% CI 26.16 to 66.84, P = 0.043) (Fig. 2C) (Table 3).

The procedures had an average shorter duration in the control group but requiring a higher amount of propofol for the maintenance of sedation (165.5 ± 65.2 mg vs 127 ± 48.6, 95% ci 1.71 to 75.29, P = 0.040) (Fig. 3A) and a longer discharge time (21.8 ± 9.3 min vs 16.3 ± 2.8, 95% ci 1.71 to 75.29, P = 0.018) (Fig. 3B) (Table 3).

In terms of adverse events no arrhythmic episodes, hiccups and vomiting were reported in both groups; episodes of cough and increased secretions occurred in both group with no statistical difference. No episodes of bronchospasm were detected and procedure interruption was necessary only once (control group) (Table 3).

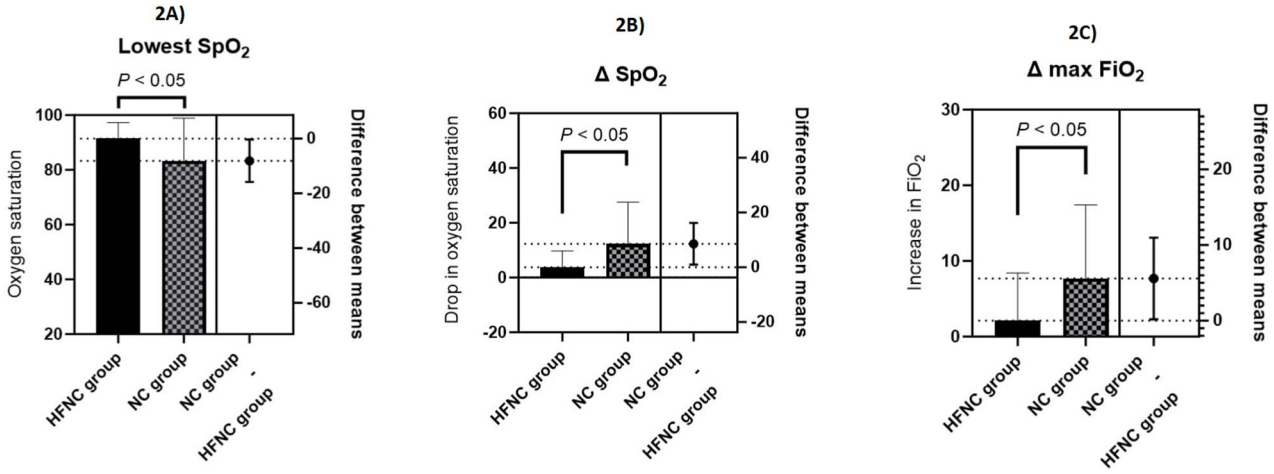

Fig. 2 (2**A)** Lowest Oxygen Saturation; (2**B**) Drop in in Oxygen Saturation; (2**C**) Increase in FiO2 delivered

Table 3 Endpoints evaluated during procedure

	HFNC group (*n* = 20)	NC group (*n* = 20)	P
Lowest SpO_2 (%)	91.4 ± 5.9	83.2 ± 15.6	*P* = 0.041
Δ SpO2	3.8 ± 5.9	12.3 ± 15.3	*P* = 0.029
Δ Max FiO_2	2.1 ± 6.3	7.7 ± 9.7	*P* = 0.043
Procedure duration (min)	22.4 ± 4.5	20.0 ± 5.4	*P* = 0.18
Discharge time (min)	16.3 ± 2.8	21.8 ± 9.3	*P* = 0.018
Propofol (mg)	127 ± 48.6	165.5 ± 65.2	*P* = 0.040
Desaturation %	30.00%	55.00%	*P* = 0.20
Duration hypoxia (")	90 ± 37.9	120 ± 39.2	*P* = 0.040
Arrhythmias	0 (0%)	0 (0%)	*P* > 0.99
Hiccups	0 (0%)	0 (0%)	*P* > 0.99
Cough	2 (10%)	7 (35%)	*P* = 0.1
Vomiting	0 (0%)	0 (0%)	*P* > 0.99
Secretions	5 (25%)	8 (40%)	*P* = 0.5
Bronchospasm	0 (0%)	0 (0%)	*P* > 0.99
Interruption	0 (0%)	1 (5%)	*P* > 0.99
IOT	0 (0%)	0 (0%)	*P* > 0.99
SBP > 160 mmHg	3 (15%)	4 (20%)	*P* > 0.99
DBP > 100 mmHg	2 (10%)	0 (0%)	*P* = 0.5
SBP < 90 mmHg	0 (0%)	2 (10%)	*P* = 0.5
DBP < 60 mmHg	0 (0%)	2 (10%)	*P* = 0.5

No significant differences were found in terms of the vital parameters at the end of the procedure (Table 2). and in terms of pre and post procedural oxygen saturation (data not shown).

The number of lymph nodes biopsied was comparable between the two groups: 1.75 ± 0.64 (range 1–3) in the HFNC group versus 1.65 ± 0.67 (range 1–3) in the CN group (t-test, *P* = 0.63).

No statistical difference in terms of diagnostic accuracy was detected (85% in HFNC group, 80% control group).

Discussion

EBUS-TBNA has become an effective and minimally invasive diagnostic method widely used for the diagnosis and staging of lung cancer [1, 21, 22]. It is considered a procedure that requires highly qualified staff and greater attention compared to conventional bronchoscopy [23]. The complications, although rare, can occur throughout the procedure with a heterogeneous degree of relevance. Data from the Aquire database, the first great prospective study [24] which had as primary end-point the incidence of complications during Ebus-Tbna, showed that the most frequent were respiratory failure (0.2%) and sustained hypoxia (0.3%), defined as saturation of oxygen < 90% For > 1 min [17, 24]. This complication may be consequence of ventilation-perfusion mismatch caused by the presence of the fibroscope which generates an increase in airways resistance [25].

Ebus-Tbna can be performed by keeping patient in a state of deep sedation that offers the right comfort and at the same time warrant spontaneous breathing limiting episodes of desaturation and alterations in hemodynamics.

The cases reported by Viedma et al. in 2016 demonstrated fewer respiratory and non-respiratory complications when midazolam and propofol were used in combination for sedation [26, 27]. However, patients undergoing the procedure are elderly with multiple comorbidities, that require complex management during the pre-, intra- and post-procedural phases. Indeed, high ASA score is associated with greater incidence of respiratory complications including severe and sustained hypoxemia or bronchospasm [27].

Generally the procedures are performed administering oxygen by low flow systems, such as nasal cannulas, which however provide an inconsistent FiO_2 and do not ensure pre-heating and humidification of the gas that can favour side effect such as drying mucosa, nasal pain,

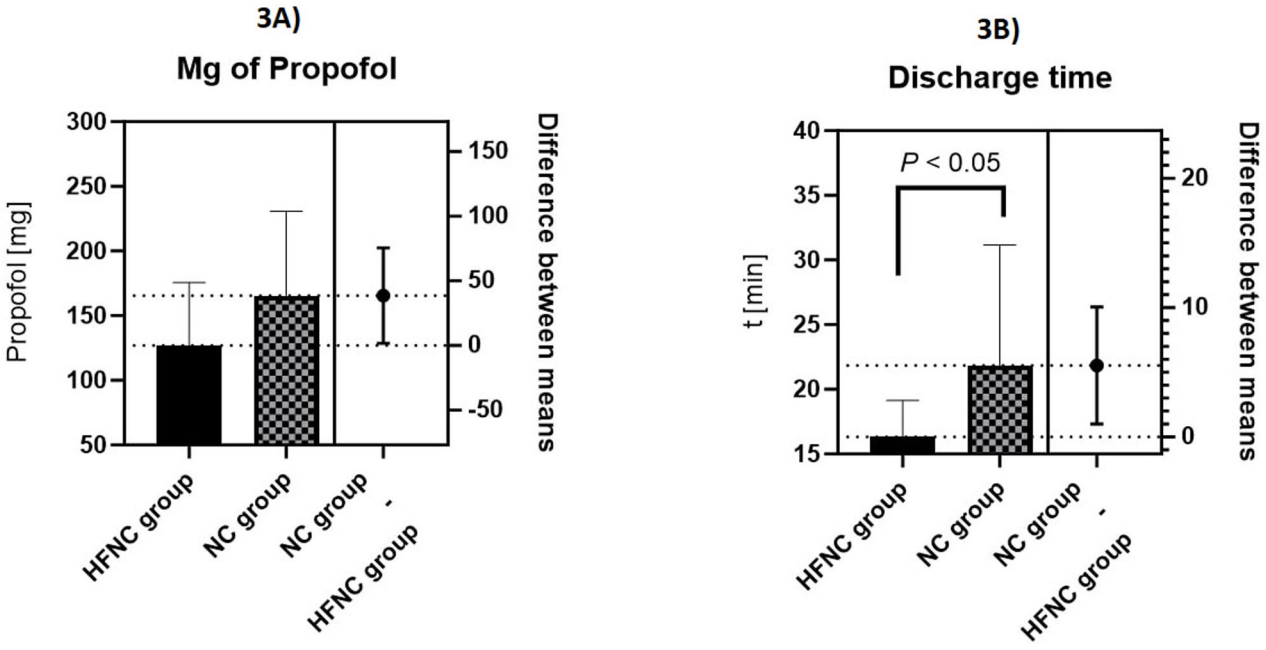

Fig. 3 (3**A**) Amount of propofol used in the two groups; (3**B**) Discharge time

mucociliary impairment, bronchospasm [9, 14, 28, 29] and respiratory exchanges alterations.

In this study, the results obtained from the use of high flow oxygen nasal cannulas showed a significant effect in reducing the severity of desaturation events compared to traditional nasal cannulas in a population of patients suffering from various comorbidities belonging to class III of the ASA scale and therefore considered to be at high anaesthetic risk.

In recent years, the use of high flow oxygenation systems has been significantly employed in numerous areas. It has been proven to be a valid resource even in intensive care settings in post-extubation patients where its use has shown a reduction in the risk of re-intubation compared to conventional oxygen therapy. Our study aligns with previous evidence demonstrating that the drop in saturation in the HFNC group was smaller compared to the control group as well as the duration of hypoxic episodes. Overall it resulted that HFNC patients had a significantly reduction on the delivered FiO_2. However, we did not demonstrated reduction in the number of events, although there was a positive trend in the HFNC group that probably do not reached statistical significance due to limited sample size.

The advantages offered by high-flow oxygen nasal cannulas compared to conventional oxygen therapy are now well known. In addition to promoting secretions clearance, minimizing the risks of atelectasis phenomena by supplying heated and humidified gases, it allows to maintain a stable FiO_2 by delivering oxygen at high flows that is less affected by variations in the patient's breathing during the procedure [9, 30, 31].

It is established that HFNC produces a flow-dependent improvement in gas exchange reducing respiratory rate maintaining constant tidal volume. This results in a reduction in the patient's work of breathing and of dead space promoting CO_2 (Carbon dioxide) washout [32]. Furthermore, the high flow generates a positive pressure, resulting in an increase in end-expiratory lung volume [31]. This phenomenon facilitates the opening of the small airways, favouring the recruitment of collapsed alveoli. This effect, at least partially, balances the hypoxic mechanism related to the presence of the bronchoscope and to upper airways muscles relaxation induced by the sedation itself, allowing to bypass the obstruction and facilitating ventilation [25].

In this study high flow oxygenation was guaranteed by means of the Optiflow Thrive system which allows setting a flow of up to 60 L/min and an FiO_2 of 100%. In cases of desaturation, the fraction of oxygen delivered was promptly modified based on the patient's needs. In the HFNC group the duration of hypoxic events was significantly shorter than that in the nasal cannulas group probably due to the reduced loss of oxygen from the system despite changes in the patient's respiratory mechanics and to the PEEP effect generated by the high flow.

In line with existing literature, our findings confirm the effectiveness of high-flow nasal cannula in reducing hypoxemic events during bronchoscopic procedures. The meta-analysis by Su et al. (2021) demonstrated that HFNC significantly reduces the incidence of desaturation

compared to conventional oxygen therapy, highlighting its potential in improving oxygenation during fiberoptic procedures [33]. Similarly, Arias-Sanchez et al. (2023) reported that patients receiving HFNC during bronchoscopy experienced fewer and less severe desaturation episodes compared to those treated with standard oxygen therapy [34].

Our results are consistent with these studies, further supporting the role of HFNC in maintaining adequate oxygenation during procedures with a high risk of desaturation, and advocating for a broader application of HFNC during EBUS-TBNA in appropriately selected patients. However in our population we observed a 30% incidence of hypoxemia ($SpO_2 < 90\%$) despite the use of HFNC. This rate is somewhat higher than that reported in previous studies using HFNC during bronchoscopy, which typically ranged from 6 to 15% (Su et al., 2021; Sharma et al., 2023; Irfan et al., 2021). This discrepancy may reflect the greater anAesthetic risk of our cohort, the use of deep sedation, and the invasive nature of EBUS-TBNA, which may increase ventilation–perfusion mismatch.

During episodes of desaturation the requirement to access to patient's airways increases significantly and may cause a temporary interruption of the procedure due to manual manoeuvres aimed to restore the correct ventilation and to remove secretions. In favour of the safety profile of HFNC, it is worth considering that, although not statistically significant, the episodes of coughing and secretion accumulation were greater in the group oxygenated with traditional nasal cannulas; therefore the maintenance of more stable oxygenation allowed to reduce temporary interruptions of EBUS-TBNA.

Furthermore we found that, although procedure time was longer in the HFNC group likely due to greater patient stability, there was a significantly lower requirement of hypnotic drugs. On the other hand, the link between the extent of sedation and increased frequency of hypoxic episodes has been already established [35].

It is important to consider the role that sedation may play in desaturation events, given its impact on the patient's respiratory drive. Balancing an adequate depth of sedation with respiratory safety is complex and requires personalized strategies, as well as careful and continuous monitoring, in order to minimize risks and optimize clinical outcomes. In this context, the use of bispectral index (BIS) monitoring can provide valuable support in maintaining stable and appropriate sedation levels, helping to avoid both excessive depth and undesirable lightening of sedation. Sedation depth was assessed qualitatively using a common used but non-continuous tool with RASS scores. However, BIS monitoring was not employed, and continuous monitoring of sedation depth was not performed. Future studies should incorporate BIS or equivalent tools to more precisely evaluate the relationship between sedation depth and hypoxemic events.

Moreover, obesity is one of the main predictive factors for the development of desaturation episodes. Although BMI (body mass index) was recorded and the two groups were comparable, no subgroup analysis based on weight status was performed. Considering that obesity is associated with an increased risk of desaturation during sedation, future studies are encouraged to include a post hoc analysis stratified by BMI tertiles in order to more precisely explore this association.

Although deep sedation with spontaneous breathing represents a logistically and clinically advantageous choice during EBUS-TBNA, and proved to be an effective and safe strategy in our study, it may be useful to evaluate the choice between deep sedation and general anaesthesia on a case-by-case basis, taking into account clinical characteristics, anaesthetic risk, and the anticipated tolerance to the procedure, with the goal of ensuring maximum safety and procedural success.

On the other hand, the use of high-flow nasal cannula oxygen therapy has shown a significant role both in the prevention of desaturation episodes, thanks to improved ventilatory support and effective dead space washout, and in the rapid resolution of intra-procedural desaturation, contributing to the maintenance of respiratory stability even under deep sedation.

Respiratory complications related to EBUS-TBNA can extend beyond the end of the procedure and in some cases require oxygen supplementation. Therefore, in cases where prolonged and high-level desaturation events occur, it is advisable to monitor the patient for a longer period of time. From the data of our study it is possible to highlight that in the HFNC group, in which the severity of the desaturations was significantly lower, the discharge times were shorter compared to the control group.

Conclusions

In conclusion our results, in line with previous studies [17, 36, 37], support high oxygen flow nasal cannulas as an effective tool to limit the severity of episodes of desaturation and hypoxia. However, it is appropriate to further investigate possible adverse events related to hypoxia in larger cohort of patients also evaluating gas exchange with accurate CO_2 measurements, and more precisely evaluating the depth of anaesthesia. Larger multi-center trials are needed to confirm these preliminary findings and to achieve greater statistical significance and while both groups were similar in baseline characteristics, the possibility of time-based confounders or unmeasured biases cannot be excluded. Future randomized trials are warranted to confirm these findings. The innovation of this work is represented by testing the effectiveness of HFNC in a population of complex patients, at high

anaesthetic risk. Furthermore EBUS-TBNA was conducted, differently from previous studies, maintaining a state of deep sedation in spontaneous breathing with the use of propofol and midazolam in combination with good outcomes.

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Authors' contributions
All authors (Pasquale De Vico, Lavinia Aluisantonio, Stefano Verri, Sara Peruzzi, Paola Rogliani, Mario Dauri, Ermanno Puxeddu) contributed equally to the manuscript and read and approved the final version of the manuscript.

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Data availability
The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
All subjects provided written informed consent for inclusion before they participated in the study. This study was conducted in accordance with the Declaration of Helsinki of 1975 (as revised in 2013), and the protocol was reviewed and approved by the Institutional Review Board (or Ethics Committee) of University of Rome Tor Vergata (protocol identification number 239.22).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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