SYSTEMATIC REVIEW

The Impact of High-flow Nasal Cannula vs Other Oxygen Delivery Devices during Bronchoscopy under Sedation: A Systematic Review and Meta-analyses

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Abstract

Background: The widespread diagnostic and therapeutic application of bronchoscopy is often associated with complications like desaturation. This systematic review and meta-analysis intend to scrutinize whether the high-flow nasal cannula (HFNC) is advantageous for providing respiratory support during bronchoscopic procedures under sedation, in comparison with other conventional modalities for oxygen therapy.

Materials and methods: A thorough screening of electronic databases was done till 31st December 2021 after obtaining registration in PROSPERO (CRD42021245420). Randomized controlled trials (RCT), evaluating the impact of HFNC and standard/any other oxygen-delivery devices during bronchoscopy were included in this meta-analysis.

Results: We retrieved in nine RCTs, with a total of 1306 patients, the application of HFNC during bronchoscopy led to decreased number of desaturation spells [relative risk (RR) 0.34, 95% confidence interval (CI) 0.27–0.44, $I^2 = 23\%$], higher nadir value of SpO_2 [Mean difference (MD) 4.30, 95% CI 2.41–6.19, $I^2 = 96\%$], and improved PaO_2 from baseline (MD 21.77, 95% CI 2.8–40.74, $I^2 = 99\%$), along with similar $PaCO_2$ values (MD –0.34, 95% CI –1.82 to 1.13, $I^2 = 58\%$) just after the procedure. However, apart from desaturation spell, the findings are significantly heterogeneous. In subgroup analysis, HFNC had significantly lesser desaturation spells and better oxygenation than low-flow devices, but in comparison to noninvasive ventilation (NIV) had a lower nadir value of SpO_2 with no other significant difference.

Conclusion: High-flow nasal cannula led to greater oxygenation and prevented desaturation spells more effectively in comparison with low-flow devices like nasal cannula, venturi mask, etc., and may be considered as an alternative to NIV during bronchoscopy in certain high-risk patients.

Keywords: Bronchoscopy, High-flow nasal cannula, Noninvasive ventilation.

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Highlights

In comparison with conventional oxygen-delivery devices HFNC during bronchoscopy provides:

- ↓Number of desaturation spells (RR 0.34, 95% CI 0.27–0.44, $I^2 = 23\%$).
- Higher nadir value of SpO_2 (MD 4.30, 95% CI 2.41–6.19, $I^2 = 96\%$).
- Improved PaO_2 from baseline (MD 21.77, 95% CI 2.8–40.74, $I^2 = 99\%$).
- Novel alternative to NIV.

Introduction

Since the first use by Killian in 1898, bronchoscopic procedures have revolutionized both in terms of instrument improvement, safety, as well as techniques, and have become an indispensable tool for various diagnostic and therapeutic purposes.[1,2] As the airway is shared between the bronchoscopist and the physician, it poses that maintaining ventilation during bronchoscopy is uniquely challenging. To overcome this, varied techniques have been used with varying success rates, e.g., controlled ventilation, NIV, intermittent apneic oxygenation, jet ventilation, etc.[3] While performing bronchoscopy in awake patients, some sedatives are given, which may lead to hypoventilation, while turbulent flows generated due to airway narrowing lead to hypoxia in around 24% cases.[4] Airway bleeding, pneumothorax, and endotracheal intubation constitute around 0.3–0.637% of the complications observed during the procedure, which culminate into 0.013% mortality.[5,6] Erratic and shallow respiration cause room-air entrainment and dilution of the fraction of oxygen (FiO_2) delivered during low-flow oxygen delivery, necessitating the use of high-flow devices and positive pressures to mitigate airway collapse.[7] Though NIV has been used traditionally, its use is criticized due to a multitude of factors like dryness of mouth, pressure sores, volutrauma, and

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delay in intubation.[2,8] Since the advent of HFNC, it has garnered considerable attention as an ideal method of maintaining oxygenation during bronchoscopy. By supplying preheated and humidified oxygen through a nasal cannula at flow rates as high as 60 L/min, HFNC becomes useful in challenging situations like in patients already suffering from hypoxemic respiratory failure.[9]

Although the efficacy of HFNC during bronchoscopy in reducing hypoxemic episodes is promising in comparison with low-flow oxygen-delivery devices,[10,11] comprehensive evidence of its utility over conventional oxygen-delivery devices, including NIV, is not well-established. Thus, the purpose of this systematic review is to summarize the effects of HFNC on desaturation episodes, the nadir value of SpO_2 during the procedure, and the impact on arterial blood gas parameters in comparison with all the conventional devices for oxygen delivery, including NIV. The Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) statement was followed for conducting this systematic review and meta-analysis.[10]

Materials and Methods

Protocol and Registration

The protocol of this systematic review and meta-analyses was prospectively enlisted in PROSPERO (ID: CRD42021245420) and did not deviate significantly from the published protocol.

Search Strategy

A comprehensive literature search was carried out among the articles published on the electronic databases (PubMed, Medline, Embase, and Cochrane database), Google Scholar (https://scholar.google.com), and preprint platforms MedRxiv (https://www.medrxiv.org) and Clinical trial database (https://clinicaltrials.gov) till 31st December 2021, independently by three researchers (AR, SRC, and SS) with the following predefined keywords ("HFNC" OR "high-flow nasal oxygen therapy" OR "high-flow nasal cannula oxygen" OR "humidified high-flow nasal cannula" OR "HHFNC" OR "Oxygen therapy") AND ("bronchoscopy" OR "rigid bronchoscopy'' OR "flexible bronchoscopy" OR "FOB").

Inclusion and Exclusion Criteria

Only the RCTs comparing HFNC with other devices for oxygen delivery either of low-flow oxygen therapy (LFOT) or NIV as an aid during bronchoscopy in nonintubated patients, were incorporated.

The controlled clinical trials, prospective and retrospective comparative cohort studies, case–control studies, cross-sectional studies, and case series in adults without any appropriate control group, studies with intubated patients, and studies except in English, without full retrievable text, were excluded (PRISMA flow diagram).

Hypoxia or desaturation episodes were defined as SpO_2 <90%, irrespective of duration.

Study Selection

The potential articles were initially screened for the titles and abstracts from the databases, with the above medical subheading (MeSH) terminology for removing the duplications and excluding the irrelevant articles. Then the full-texts of the eligible studies were evaluated to check the inclusion criteria by three independent researchers (AR, SRC, and SS). Any disagreement on the inclusion of the article was settled after discussion with another co-author (PK).

Data Extraction

Relevant data of each article regarding the first author, year of publication, place, population, methodology (flow and FiO_2 of HFNC), and outcomes (desaturation spells, lowest SpO_2, $PaCO_2$, and change in PaO_2) were extracted independently by AR and SRC with a preconceived data-extraction sheet. Supplementary data were searched for each article. A consensus among authors was reached when conflict occurred by discussion with SS.

The number of incidents and the total number of patients in each group were recorded for dichotomous data, and means and SD were extracted for continuous data. Studies with missing data have been reported descriptively.

Risk of Bias Assessment

SS and DH independently assessed any potential bias in selected RCTs by using the RoB 2.0 tool,[11] which comprises five domains: "randomization process", "deviations from intended interventions", "missing outcome data", "measurement of the outcome", and "selection of the reported result", and each domain was graded as "Low", "Moderate", "Serious", and "Critical". Any difference of opinion was resolved by consulting with PK.

Quality of the Evidence

SS and DH independently assessed the quality of evidence with the "Grading of Recommendations Assessment, Development and Evaluation (GRADE)" tool, comprising five downgrading factors (study limitations, indirectness, imprecision, consistency of effect, and publication bias) and three upgrading factors ("dose–response relation, large magnitude of the effect, and plausible confounders or biases").[12,13] The quality of evidence of every outcome is categorized as "High", "Moderate", "Low", or "Very low".[14–20] The difference of opinion was resolved after consulting with PK.

Data Synthesis

SS used Review Manager version 5.4 to conduct this meta-analysis. Risk ratio was used for denoting the effect-size measure of dichotomous data. The continuous variables were expressed in MDs along with the 95% CIs according to the Cochrane Handbook for Systematic Reviews of Interventions.[21] Heterogeneity was expressed by I^2, and a value of >50% was accepted as significant heterogeneity.

Results

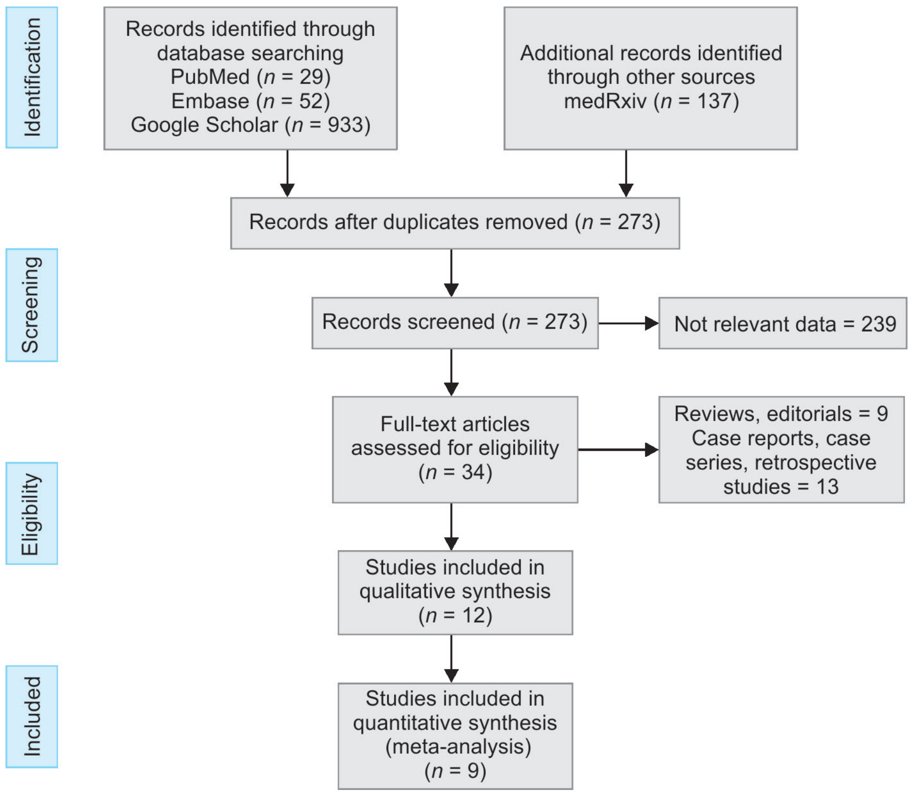
Basic Characteristics

We included nine randomized[22–30] controlled studies out of 273 identified publications in this review, after satisfying the inclusion criteria (Flowchart 1 and Table 1). The overall risk of bias was low in the included studies with some concerns (Fig. 1).

Seven studies included normoxemic/nonhypoxemic patients[22–26,29,30] and the rest two[27,28] were carried out on hypoxemic patients (P/F ratio <300 mm Hg or PaO_2 <70 mm Hg), requiring higher (60–100%) FiO_2 during bronchoscopy.[22,23] All included studies had applied HFNC in one arm, with flows ranging from 30 L[26] to 60 L/min,[25] and FiO_2 (range 40–100%) titrated to maintain SpO_2 ≥95%. The comparator arm comprised of NIV in two studies,[27,28] venturi mask in one study[25] and low-flow devices, e.g., nasal cannula and face masks in rest.[22–24,26,29]

The bronchoscopy was performed orally with local anesthetic (Lignocaine) spray throughout the passage (e.g., oropharynx,

Flowchart 1: PRISMA-2009 flow diagram



airway) of the scope in all the studies along with the following different combinations for sedation: short-acting opioids (fentanyl/alfentanil/remifentanil),[25–28] intravenous propofol,[26,28] and midazolam.[23,25,26,29]

Meta-analysis

Desaturation Episodes during Procedure

The risk of desaturation (SpO_2 <90%) during bronchoscopy was assessed in nine articles with a total of 1306 patients. Overall, the risk of desaturating episodes was lower among the patients having HFNC (RR 0.34, 95% CI 0.27–0.44, I^2 = 23%) in comparison with patients with other oxygen-delivery devices during bronchoscopy.

In subgroup analyses, patients with HFNC were found to have a significantly lesser risk of desaturation (RR 0.34, 95% CI 0.26–0.44, I^2 = 28%) than the patients having low-flow oxygen devices during bronchoscopy. However, HFNC seems to be equivocal to patients having NIV during the procedure in terms of desaturation episodes (RR 0.44, 95% CI 0.10–1.88, I^2 = 51%) (Fig. 2).

Nadir Lowest SpO_2 Level

Seven studies with 1091 patients assessed the nadir lowest SpO_2 level during the procedure. The patients with HFNC showed significantly higher nadir lowest SpO_2 (MD 4.3, 95% CI 2.41–8.07, I^2 = 97%) in comparison with patients having other oxygen-delivery devices.

In subgroup analyses, patients with HFNC had significantly higher lowest nadir value of SpO_2 (MD 6.22, 95% CI 4.36–8.07, I^2 = 96%) than the patients having low-flow oxygen devices. However, patients having NIV during the procedure had an even higher nadir value of SpO_2 (MD –2.63, 95% CI –4.99 to –0.28, I^2 = 0%) in comparison with patients receiving HFNC (Fig. 3).

Difference of PaO_2

The difference of PaO_2 from baseline to just after the completion of the procedure is assessed in three studies among 132 patients. High-flow nasal cannula showed significantly improved oxygenation (MD 21.77, 95% CI 2.8–40.74, I^2 = 99%) immediately after bronchoscopy than other oxygen-delivery devices.

In subgroup analyses, patients with HFNC were found to have an improved PaO_2 from baseline to just after the procedure (MD 32.19, 95% CI 11.76–52.63, I^2 = 100%) in comparison with patients having low-flow oxygen devices during bronchoscopy. However, the patients having NIV during the procedure did not show any significant difference in PaO_2 from baseline to just after the procedure (MD –25.7, 95% CI –59.24 to –7.84) in comparison to patients who received HFNC (Fig. 4).

Level of $PaCO_2$

The level of $PaCO_2$ immediately after the procedure was assessed in three studies among 121 patients. The post-procedure $PaCO_2$ level was not significantly different in patients with HFNC in comparison to patients with low-flow oxygen delivery devices (MD –0.34, 95% CI –1.82 to 1.13, I^2 = 58%) (Fig. 5).

Significant heterogeneity is found among studies assessing nadir lowest SpO_2 level, a difference of PaO_2 from baseline, and subgroup analysis in patients with low-flow oxygen devices during bronchoscopy for the lowest nadir value of SpO_2 and difference of PaO_2 from baseline.

Quality of Evidence

The quality of evidence on the utility of HFNC during bronchoscopy is of low quality. Remarkable indirectness was found in terms of the difference in population and outcome measures (Table 2).

Table 1: Characteristics of included studies

Sl. no.	*Author[ref] year* *Design*	*Patient* *Bronchoscopy procedure*	*Country* *Sample size*	*Intervention*	*Comparator*	*Primary outcome*	*Adverse events other than hypoxia mentioned*
1.	Douglas et al.[24] 2017	Patients undergoing EBUS; nonhypoxemic	Australia	HFNC with flows 50 (IQR 30–70) L/min	Oxygen with bite block 10–15 L/min	Though the number of desaturation episodes were lower with HFNC, the finding was not statistically significant	None
	RCT, SC	Midazolam + remifentanil sedation targeting MOAA 4; via mouth	60				
2.	Irfan et al.[25] 2021	Evaluation by EBNA; non-hypoxemic	UK	HFNC	Nasal prongs	HFNC is associated with significantly lower desaturation episodes	None
	RCT, SC	Orally under midazolam + alfentanil sedation	40				
3.	Longhini et al.[26] 2021	OPD patients undergoing FOB	Italy	HFNC FiO_2 21% (if SpO_2 >95%) or adjusted to maintain SO_2 >95%;	Standard oxygen 2 L/min (FiO_2 0.3)	HFNC provided better oxygenation, end-expiratory lung volume, and prevented raised diaphragm activation	No respiratory support escalation
	RCT, SC	Orally with lignocaine various amounts; no sedation	36				
4.	Lucangelo et al.[27] 2012	Nonhypoxemic	Italy	*Group I* HFNC 50% FiO_2 and 60 L/min flows *Group II* 50% FiO_2 and 40 L/min flows	Venturi mask 50% FiO_2 and 40 L/min flows	HFNC with 60 L/min flows produced better oxygenation. However, with 40 L/min, both the Venturi mask and HFNC had similar results	None
	RCT, SC	Orally and lignocaine spray + midazolam sedation	45				
5.	Menachem et al.[28] 2020	Post-lung transplant nonhypoxemic	Australia	HFNC	Low-flow nasal oxygen	Hypoxia was significantly lower in patients receiving HFNC	Airway manipulation HFNC 4 (2–7) vs low flow 1 (1–3)
	RCT, SC	Orally; midazolam/propofol/alfentanil sedation	76				

6.	Saksitthichok et al.[29] 2019	Preexisting hypoxia PaO_2 <70	Thailand	HFNC 40 L/min [mean 38.6 (7.9)] 60% FiO_2	NIV EPAP 5 cm H_2O and IPAP at least 10 cm H_2O (12.3 ± 2.1) to maintain tidal volume >8 mL/kg	Both NIV and HFNC had similar effectiveness for preventing hypoxemia	1 pneumothorax; <8 hour NIV 5 vs HFNC 1ETI; 28 day mortality NIV 12% vs HFNC 3.8%
	RCT, SC	Via mouth under fentanyl + lignocaine SAGO	51				
7.	Simon et al.[30] 2014	Critically ill patients; hypoxemic with P/F ratio <300	Germany	HFNC	NIV IPAP 15–20 cm H_2O and EPAP 3–10 cm H_2O	HFNC was well-tolerated during bronchoscopy in patient with stable oxygenation. However, NIV provided better oxygenation in patients with moderate-to-severe hypoxemia	3 NIV vs 1 HFNC <8 hour ETI; 24 hour NIV 65% vs HFNC 45% ETI
	RCT, SC	Orally; lignocaine spray + propofol 10–20 mg boluses every 3–5 minutes	40				
8.	Ucar et al.[31] 2020	Patients undergoing EBUS	Turkey	HFNC	Conventional nasal cannula	HFNC was safer and more effective than conventional nasal cannula.	Arrhythmias conventional group III vs HFNC
	RCT, SC	Orally; sedation midazolam + lignocaine	170				
9.	Wang et al.[32] 2021	Patient undergoing diagnostic bronchoscopy with SpO_2 >90	China	HFNC	Nasal prongs FiO_2 24–45% flow rates up to 6 L/min	HFNC reduces desaturation episodes (SpO_2 <90%) during bronchoscopy and thereby shortens the duration of procedure	Lesser incidence of agitation (11.0% vs 19.2%, $p = 0.001$) and supraventricular tachycardias (1.0% vs 3.0%, $p = 0.045$), and pneumothorax (2.6% vs 5.8%, $p = 0.022$) with HFNC in comparison to patient receiving conventional oxygen therapy.
	RCT, SC	2% Lidocaine was nebulization, and no sedatives were used	788				

EBUS, endobronchial ultrasound; EBNA, endobronchial needle aspiration; ETI, endotracheal intubation; FOB, fiber-optic bronchoscopy; IQR, interquartile range; MOAA, modified observer assessment of alertness scale; P/F, PaO_2/FiO_2 ratio; RCT, randomized control trial; SAGO, spray as you go; SC, single center

Publication Bias

We assessed publication bias for the studies on desaturation episodes during bronchoscopy. The Funnel plot indicates a publication bias is unlikely.

Discussion

The present study showed low-quality evidence with variability among the HFNC-enabled patients undergoing bronchoscopy to attain better PaO_2 and nadir value of SpO_2 after initiation of the procedure and helped to alleviate desaturation spells without causing derangement of ventilation. The above-mentioned benefits of HFNC were more evident when compared with low-flow devices such as venturi mask and nasal cannula, however, in comparison with NIV, these effects were equivocal.

Similarly, several systematic reviews also acknowledged the utility of HFNC for decreasing the requirement of mechanical ventilation in comparison with conventional oxygen therapy during

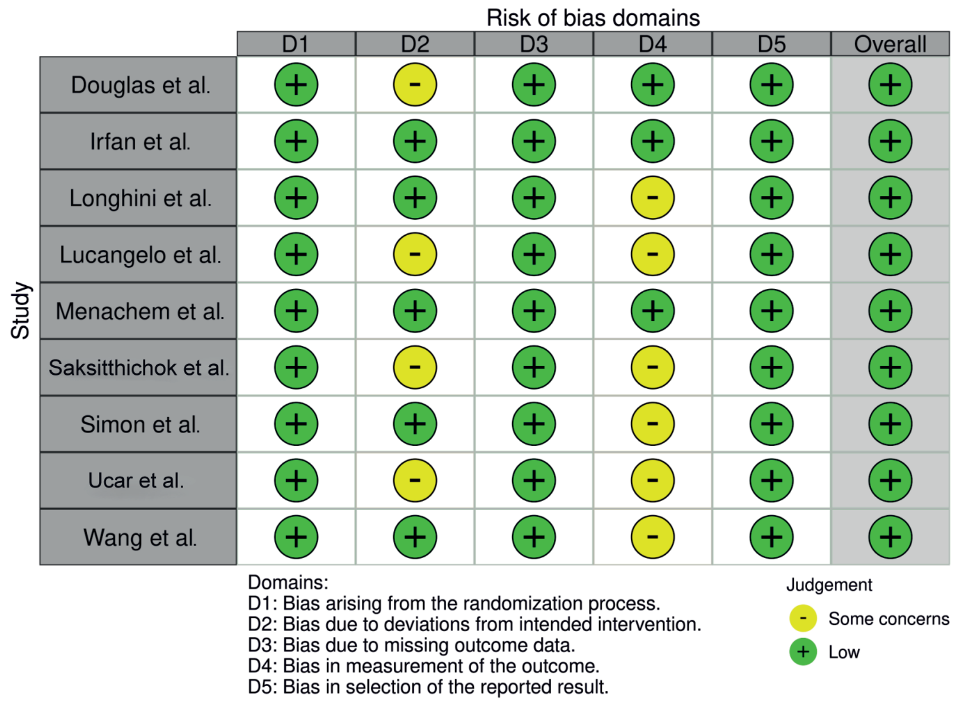


Fig. 1: RoB 2 tool assessment for the included RCTs

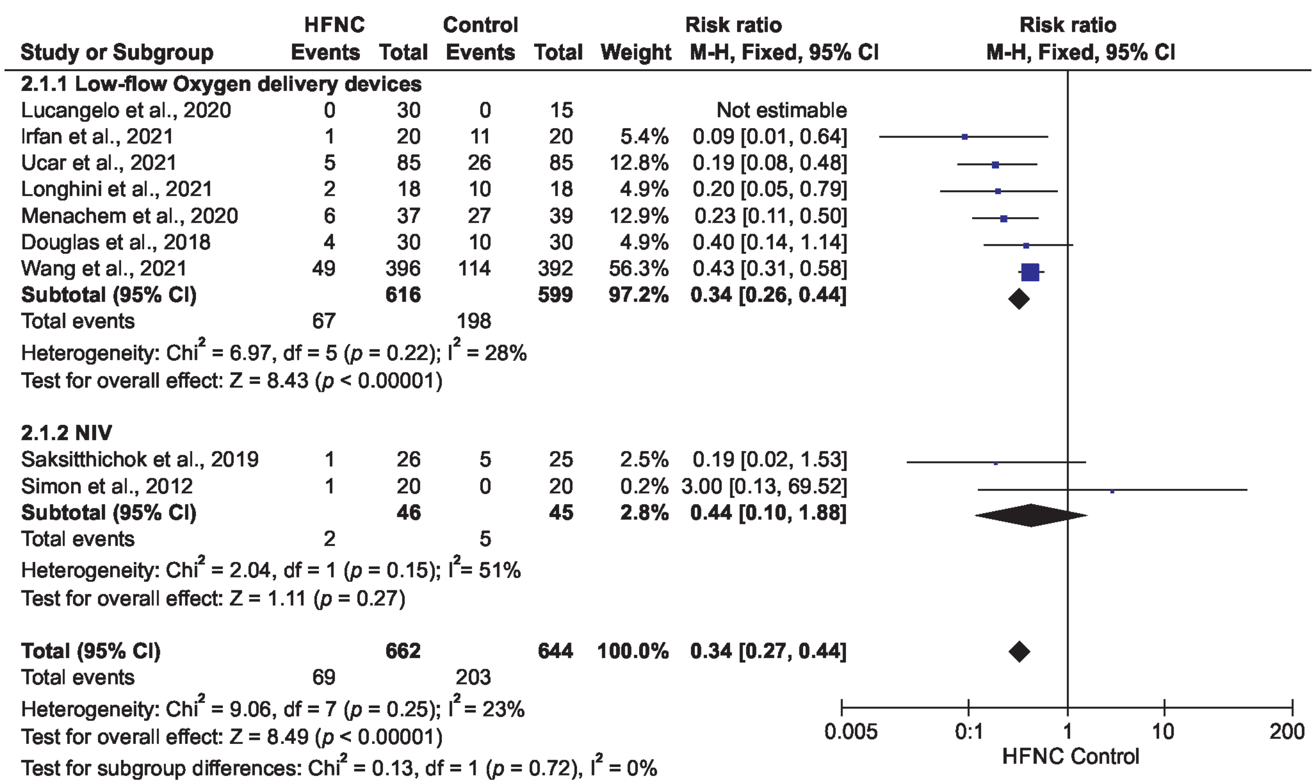


Fig. 2: The impact of HFNC on desaturation episodes during bronchoscopy

Study or Subgroup	HFNC Mean	HFNC SD	HFNC Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, Random, 95% CI
3.1.1 Low-flow oxygen delivery devices								
Douglas et al., 2018	97.3	1.2	30	91.8	1.7	30	16.4%	5.50 [4.76, 6.24]
Irfan et al., 2021	97.5	3.5	20	88.3	5	20	12.6%	9.20 [6.53, 11.87]
Longhini et al., 2021	95	0.5	18	89.3	2.1	18	16.1%	5.70 [4.70, 6.70]
Menachem et al.,2020	94.1	1.6	37	86.1	2.1	39	16.3%	8.00 [7.16, 8.84]
Wang et al., 2021	94.1	3.2	392	90.5	3.8	396	16.7%	3.60 [3.11, 4.09]
Subtotal (95% CI)			**497**			**503**	**78.1%**	**6.22 [4.36, 8.07]**
Heterogeneity: $Tau^2 = 4.04$; $Chi^2 = 93.60$, df = 4 (p <0.00001); $I^2 = 96\%$								
Test for overall effect: Z = 6.58 (p <0.00001)								
3.1.2 NIV								
Saksitthichok et al., 2019	92.2	6.6	26	94.6	4.2	25	11.8%	–2.40 [–5.42, 0.62]
Simon et al., 2012	92	7	20	95	5	20	10.1%	–3.00 [–6.77, 0.77]
Subtotal (95% CI)			**46**			**45**	**21.9%**	**–2.63 [–4.99, –0.28]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.06$, df = 1 (p = 0.81); $I^2 = 0\%$								
Test for overall effect: Z = 2.19 (p = 0.03)								
Total (95% CI)			**543**			**548**	**100.0%**	**4.30 [2.41, 6.19]**
Heterogeneity: $Tau^2 = 5.54$; $Chi^2 = 133.86$, df = 6 (p <0.00001); $I^2 = 96\%$								
Test for overall effect: Z = 4.45 (p <0.00001)								
Test for subgroup differences: $Chi^2 = 33.46$, df = 1 (p <0.00001), $I^2 = 97.0\%$								

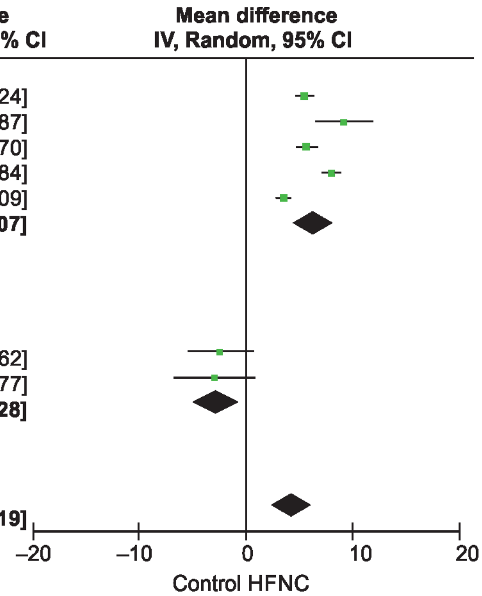


Fig. 3: The impact of HFNC on Nadir lowest SpO_2 level during bronchoscopy

Study or Subgroup	HFNC Mean	HFNC SD	HFNC Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, Random, 95% CI
4.1.1 Low-flow oxygen delivery devices								
Longhini et al., 2021	6	4.2	18	–15.75	2.8	18	40.9%	21.75 [19.42, 24.08]
Lucangelo et al., 2020	56.2	1.7	30	13.6	2.9	15	41.1%	42.60 [41.01, 44.19]
Subtotal (95% CI)			**48**			**33**	**82.0%**	**32.19 [11.76, 52.63]**
Heterogeneity: $Tau^2 = 216.32$; $Chi^2 = 209.75$, df = 1 (p <0.00001); $I^2 = 100\%$								
Test for overall effect: Z = 3.09 (p = 0.002)								
4.1.2 NIV								
Saksitthichok et al., 2019	–54.2	63.2	26	–28.5	59	25	18.0%	–25.70 [–59.24, 7.84]
Subtotal (95% CI)			**26**			**25**	**18.0%**	**–25.70 [–59.24, 7.84]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.50 (p = 0.13)								
Total (95% CI)			**74**			**58**	**100.0%**	**21.77 [2.80, 40.74]**
Heterogeneity: $Tau^2 = 227.48$; $Chi^2 = 222.73$, df = 2 (p <0.00001); $I^2 = 99\%$								
Test for overall effect: Z = 2.25 (p = 0.02)								
Test for subgroup differences: $Chi^2 = 8.35$, df = 1 (p = 0.004), $I^2 = 88.0\%$								

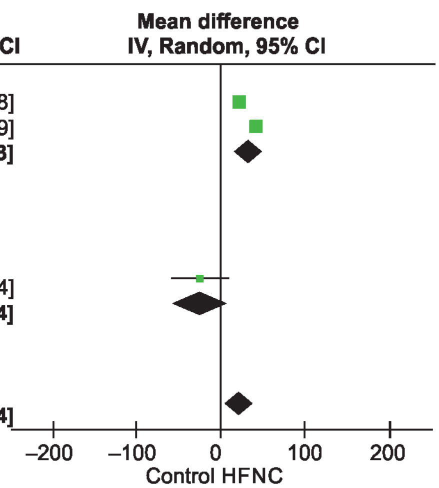


Fig. 4: The impact of HFNC on difference of PaO_2 from baseline to just after the completion of bronchoscopy

Study or Subgroup	HFNC Mean	HFNC SD	HFNC Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, Random, 95% CI
5.1.1 Low-flow oxygen delivery devices								
Irfan et al., 2021	45.7	6.7	20	44.2	8.2	20	8.7%	1.50 [–3.14, 6.14]
Longhini et al., 2021	41.3	2.2	18	42.7	1.5	18	44.0%	–1.40 [–2.63, –0.17]
Lucangelo et al., 2020	43	2.7	30	42.7	0.97	15	47.3%	0.30 [–0. 78, 1.38]
Subtotal (95% CI)			**68**			**53**	**00.0%**	**–0.34 [–1.82, 1.13]**
Heterogeneity: $Tau^2 = 0.89$; $Chi^2 = 4.78$, df = 2 (p = 0.09); $I^2 = 58\%$								
Test for overall effect: Z = 0.46 (p = 0.65)								
Total (95% CI)			**68**	**53**			**100.0%**	**–0.34 [–1.82, 1.13]**
Heterogeneity: $Tau^2 = 0.89$; $Chi^2 = 4. 78$, df = 2 (p = 0.09); $I^2 = 58\%$								
Test for overall effect: Z = 0.46 (p = 0.65)								
Test for subgroup differences: Not applicable								

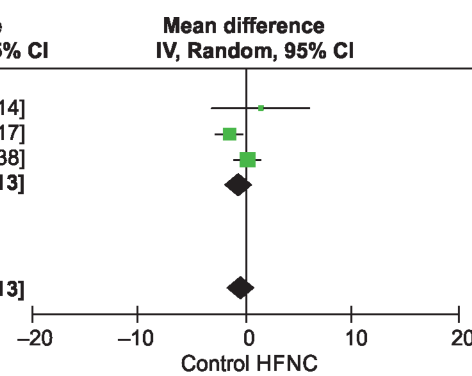


Fig. 5: The impact of HFNC on $PaCO_2$ immediately after bronchoscopy

Table 2: GRADE evidence profile of studies on COVID-19 studies

	No. of participants									
Outcome	*Total no.*	*Intervention*	*Control*	*Risk of bias*	*Inconsistency*	*Indirectness*	*Imprecision*	*Other considerations*	*Quality of evidence (Grade)*	*Relative effect*
Desaturation episodes	518	266	252	No	No	Yes	No	None	Low ⊕⊕⊖⊖	OR = 0.15 (95% CI: 0.08–0.28)
Nadir lowest SpO_2 level	303	151	152	No	No	Yes	No	None	Low ⊕⊕⊖⊖	MD = 4.39 (95% CI: 2.21–6.57)
Difference of PaO_2	132	74	58	No	No	Yes	No	None	Low ⊕⊕⊖⊖	MD = 21.77 (95% CI: 2.8–40.74)
$PaCO_2$	121	68	53	No	No	Yes	Yes	None	Very low ⊕⊖⊖⊖	MD = −0.34 (95% CI: −1.82 to 1.13)

CI, confidence interval; COVID-19, coronavirus disease 2019; GRADE, Grading of Recommendations Assessment, Development, and Evaluation; MD, mean difference; OR, odds ratio

bronchoscopy[10,11] and patients with respiratory failure.[31] Leong et al. also reported HFNC as a noninferior viable alternative for NIV in acute respiratory failure (ARF).[32]

The introduction of a bronchoscope causes luminal narrowing of the trachea, leading to partial airway closure and turbulent airflows culminating in hypoxia. Additional factors like external fluid instillation during bronchoscopy-associated lavage (BAL), use of sedatives leading to hypoventilation,[22] and ventilation–perfusion (V/Q) mismatch result in around 24% desaturation episodes during bronchoscopy.[4]

Desaturation, airway bleeding, pneumothorax, and endotracheal intubation constitute around 0.3–0.637% of complications observed during the procedure, which culminate into 0.013% mortality.[5,6] While a study reported about the requirement of immediate intubation (<8 hours) in five patients with NIV in comparison with a single patient with HFNC ($p = 0.07$),[27] in another study no more patients with NIV required intubation.[28] It is to be noted that both the studies were done on hypoxemic patients. However, normoxic patients did not require intubation.[23–25]

Both NIV and HFNC offer noninvasive options to provide higher flows, which are invaluable in immunocompromised patients.[33–35] However, the use of NIV has been associated with varying adverse effects, e.g., rhinorrhea, dryness of mouth, pressure sores, air leak, patient–ventilator asynchrony, and generation of self-inflicted lung injury (SILI) in patients with hypoxemic respiratory failure.[8,32,33] These limitations with the use of NIV have garnered interest in finding an alternative high-flow device, e.g., HFNC.

High mean airway pressure as well as inspiratory flows generated during NIV along with the ease of triggering enable bronchoscopy to be performed seamlessly. Saksitthichok et al. reported that use of NIV was associated with higher perceived dyspnea post bronchoscopy in comparison with HFNC.[27] Thus, ease of administration, ability to generate 'high' 'humidified' flows of up to 60 L/min alongside end-expiratory positive pressure (0.7 cm/10 L/min flows), make HFNC an attractive tool during bronchoscopy.[36] It reduced hypoxemic events below 5%[37] and alleviated intubation in hypoxemic patients.[38]

As far as the head-to-head comparison between HFNC and NIV is concerned, a various array of findings was obtained from the literature. In this review, NIV attained a greater nadir value of SpO_2 during bronchoscopy but similar PaO_2, desaturation episodes, and $PaCO_2$, as compared with HFNC. As bronchoscopy was performed via the mouth, loss of flows and thereby minimization of positive pressure could have negated the effect of HFNC.[39]

Leong et al.[32] also reported HFNC as a noninferior viable alternative for NIV in ARF. In immunocompromised individuals with hypoxic ARF, NIV had similar intubation reduction rates as compared with HFNC.[40] A meta-analysis comparing HFNC vs other modes of oxygen therapy in ARF found a similar requirement of higher ventilatory support and respiratory rate in HFNC as well as NIV.[41]

The higher FiO_2 enabled HFNC to attain greater oxygenation as compared with other low-flow devices. Similarly, HFNC performed better as compared with low-flow devices in our review also.

Though, preliminary studies emphasized better patient comfort and lesser dyspnea with HFNC, Maitra et al. did not find any benefit.[41] In this review, HFNC was found to have reduced dyspnea score[27] standard oxygen in another[29] as compared with NIV. In another study of 30 patients with ARF undergoing FOB-associated BAL, HFNC performed fairly with 5 patients

(16.67%) experiencing procedure failure and concomitant lesser device-related discomfort.[42] Similar clinical efficacy has been reported in lung transplant recipients undergoing FOB-guided lung biopsy.[43] However, three studies that compared either patient's or anesthesiologist or proceduralists' satisfaction scores had similar results.[22,23,26] Owing to the intrinsic diversity of the scales, no pooled analysis could be done.

Finally, the findings of our study should be interpreted on lines of cost-effectiveness of using HFNC as a blanket solution, as the overall incidence of hypoxemia during endoscopic procedures is less than 10% and the use of HFNC could be cumbersome, especially in normoxic patients, given its limited affordability.[44] Again, in patients with severe hypoxia (P/F ratio <200 mm Hg), its use may be guarded.[45–47] However, in the conundrum of immunocompromised patients undergoing high-risk procedures, it might be helpful. Among endoscopies, bronchoscopy carries a significantly higher risk of hypoxia (~24%) and indeed, many patients (lung carcinoma, pneumocystis pneumonia, etc.) can be immunocompromised. Therefore, HFNC remains a prudent option for such scenarios, provided timely escalation based on clinical criteria and/or scoring system.[48]

Strengths and Limitations

While the previous reviews were mainly comparing HFNC to other low-flow oxygen delivery devices, our review is more robust as we have included maximum RCTs comparing HFNC to other conventional oxygen delivery, including a subgroup analysis for NIV. Except for desaturation spells, all our study variables had significant baseline heterogeneity, owing to the nonuniformity in patient-selection criteria, indications, use of different sedative agents, and method of bronchoscopy.[49,50]

Conclusion

To conclude, HFNC provided better oxygenation and similar ventilation as compared with low-flow devices. It may be considered as an alternative to NIV in certain high-risk patients undergoing bronchoscopy. Future studies with uniform patient-selection criteria, sedation techniques, and methods of bronchoscopy are the need of the hour.

Authors' Contributions

AR: Study selection, data extraction, and drafted the paper. PK: Search strategy, study selection, risk of bias assessment, and quality of the evidence assessment. SRC: Study selection, data extraction, and drafting. DH: Risk of bias assessment and quality of the evidence assessment. SS: Conceptualization, search strategy, study selection, data extraction, data synthesis, risk of bias assessment, quality of the evidence assessment, drafted the paper, and editing.

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