Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/dsxkje33

ROLE OF LOW-FLOW VS. HIGH-FLOW OXYGEN THERAPY POST-EXTUBATION IN ICU PATIENTS

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Abstract
The post-extubation period is a high-risk time for respiratory compromise in critically ill adults, and careful oxygen therapy selection is required. Low-flow oxygen therapy (LFOT) is commonplace due to its ease and low cost, but it is not humidified and does not deliver constant FiO_2, which may compromise its clinical effectiveness. High-flow nasal cannula (HFNC) has been proposed as a more effective alternative, delivering heated, humidified oxygen at high flow rates with low-level positive airway pressure. Nevertheless, its wider application is controversial secondary to increased expense and paucity of data guiding routine use in overall ICU populations without established risk stratification. This trial compared the efficacy of HFNC versus LFOT in adult ICU patients following extubation. It meta-analyzed data from 26 peer-reviewed articles, including randomized controlled trials, cohort studies, and systematic reviews, involving 8,537 patients. Outcomes were categorized into efficacy (reintubation rates, oxygenation), patient-oriented measures (comfort, adherence), and healthcare use (ICU length of stay, equipment expenditures). HFNC drastically decreased reintubation rates in high-risk patients and enhanced both early oxygenation and patient comfort, especially during the first 24–48 hours after extubation. While HFNC was associated with more expensive daily equipment, there is evidence that decreases in ICU length of stay and reintubation can offset these expenses. Findings were less uniform within low-risk or unstratified populations, lending support to a selective as opposed to routine strategy. This review emphasizes the value of risk-directed oxygen therapy strategies and identifies HFNC as a safe and effective modality for enhancing outcomes in properly selected post-extubation ICU patients.

Keywords: High-flow nasal cannula, Intensive Care Unit, Oxygen therapy, Post-extubation, Reintubation

Introduction

When critically ill patients move from invasive mechanical ventilation to breathing on their own, it becomes a high-risk time for them. Extubation is a sign of improvement, but it also means the patient remains at risk for respiratory problems due to ongoing lung problems, tired respiratory muscles, narrowed airways, and poor secretion removal.[1] If the oxygen supply is not enough, these factors may cause respiratory failure that requires reintubation, which is linked to a greater risk of complications, longer hospital stays, a higher death rate, and higher medical costs.[2] To prevent post-extubation

failure, oxygen therapy helps keep oxygen levels normal, decreases breathing effort, and supports the patient's recovery.[3] Usually, this has been done using low-flow oxygen therapy (LFOT) with oxygen delivered through nasal cannulae or face masks at a maximum flow rate of 15 L/min. LFOT is easy to use and inexpensive, but it does not provide a steady oxygen level, humidify the air, or offer positive airway pressure. Because of these limitations, secretion may not be cleared properly, and patients may feel discomfort, which could affect the outcome of treatment.[4]
HFNC is now considered a good alternative because it provides heated and humidified oxygen at high flow rates (up to 60 L/min) with accurate control of the amount of oxygen.[5] HFNC improves breathing by reducing the amount of air that does not reach the lungs, clearing secretions, making it easier to breathe, and gently opening up the lungs.[6] Also, the open, humidified design of HFNC is usually more comfortable for patients, allowing them to communicate more easily.[7] Even though HFNC is used more often in ICUs, its use after extubation is still being discussed. HFNC seems to work well for patients with chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome (ARDS), or recent thoracic surgery, but its use in all ICU patients is not as well established.[8] There is a lot of variation in clinical practice from one institution to another, usually due to what each doctor prefers or the local standards, since there are not many risk-stratified outcome data.[9] While several studies have examined HFNC and LFOT on their own, few give direct comparisons that are suitable for specific groups of patients.[10] Because of this gap, it is difficult to choose the best oxygen therapy after a patient is taken off the ventilator.[11] A careful comparison of HFNC and LFOT in different patient groups would help fill this evidence gap and support better, more cost-effective ways of caring for patients after extubation.[12]

Study Aim and Objectives
This study aims to compare high-flow nasal cannula and low-flow oxygen therapy in adult ICU patients after they are extubated, using results from randomized trials, cohort studies, and synthesis papers. The analysis looks at clinical outcomes (reintubation and oxygenation), how patients feel (comfort and tolerance), and healthcare factors (ICU stay and cost). The specific objectives are:
1. To compare the effectiveness of HFNC and LFOT on reintubation rates, oxygenation, and respiratory effort.
2. To evaluate patient-centered outcomes, including comfort, communication ease, and overall experience.
3. To assess cost-effectiveness and resource utilization across different patient risk profiles and clinical contexts.

Methods
Study Design
This study carefully analyzed clinical results from studies that compared HFNC and LFOT in adult patients who were admitted to intensive care units (ICUs) after being extubated. No primary data were collected. The analysis was set up to look at results related to how effective the treatment was, how patients experienced care, and how much healthcare was used. All stages of study identification, selection, and analysis were carried out using a method that made the process transparent and allowed it to be repeated.

Data Sources and Search Strategy
A search of the literature was performed on PubMed, the Cochrane Library, Embase, and Google Scholar, covering research done between January 2010 and April 2025. The search strategy used both MeSH and free-text terms. The results were filtered using Boolean operators, which included a combination of the following: "high-flow nasal cannula," "HFNC," "high-flow oxygen therapy," "low-flow oxygen," "LFOT," "conventional oxygen therapy," "post-extubation," "extubated patients," "intensive care," and "ICU."Only articles written in English and about human subjects aged 18 or over were included using filters. Search terms were changed to match the way each database

indexes its information. We also checked the reference lists of eligible studies to ensure that no unindexed articles were missed.

Eligibility Criteria

Studies were included when they looked at adult patients who were extubated in the ICU and then received HFNC or LFOT. To be included, studies had to provide at least one of the following results: reintubation rate, oxygenation parameters, respiratory function, patient comfort, length of ICU stay, or healthcare resource metrics. Studies accepted for review were randomized controlled trials, cohort studies, and high-quality systematic reviews. Studies that focused on children or newborns, those not discussing oxygen therapy after extubation, and those that did not directly compare HFNC to LFOT were excluded. We did not include case reports, editorials, expert commentaries, or articles written in languages other than English.

Study Selection Process

The three phases in the study selection process were title and abstract screening, reviewing the full text, and checking for final eligibility. In the first phase, articles that were duplicates or not relevant were removed using their titles and abstracts. After that, the full text of each study was carefully examined to confirm it met the criteria for inclusion. Screening and review were conducted independently by two researchers. If there were disagreements, a third expert helped by reaching a consensus. Additional information was obtained from supplementary materials, appendices, and clinical trial registries when they were available.

Data Extraction and Outcome Classification

Using a standardized form, we extracted the first author, the year of publication, the study design, patient characteristics, oxygen delivery method, and important clinical results. The data was sorted into three clinical domains to help with a structured comparison and thematic synthesis. The first set of results from the efficacy domain looked at reintubation rates, PaO_2/FiO_2 ratios, respiratory rate, and ICU mortality. The second category, patient-centered outcomes, looked at comfort, breathing difficulty, how well the interface was tolerated, and how easy it was to communicate. The third area looked at healthcare resource indicators such as how long patients spend in the ICU, the time spent on oxygen therapy, and the expenses related to devices. Since studies used different ways to measure and report outcomes, a meta-analysis could not be done. Instead, data were analyzed using qualitative synthesis, and the findings were organized and compared by describing them in each of the three predefined domains.

Quality and Bias Assessment

The appropriate instruments for each study type were used to assess the methodological quality and bias risk of each study. Cohort studies were evaluated using the Newcastle-Ottawa Scale, and randomized controlled trials were reviewed using the Cochrane Risk of Bias Tool (RoB-2). The provided quality scores were used for meta-analyses and systematic comparisons. Despite the lack of formal scoring, the outcomes of these evaluations provided insight into each study's conclusions. Since these could impact the outcomes and the comparability of the studies, particular attention was paid to variations in the inclusion criteria, the type of treatment administered, the definition of reintubation, and the duration of follow-up. The results from studies with a higher risk of bias or unclear reporting were examined with caution when included in the overall review.

Results

Study Characteristics

Twenty-six studies were chosen for review, including 11 randomized controlled trials, 9 observational cohort studies, and 6 systematic comparisons or meta-analyses. In these studies, 8,537 adult ICU patients were extubated and then given either HFNC or LFOT. The research was done in ICUs that treated general medical, surgical, cardiothoracic, and a mixture of patients. The study also looked at

patients with chronic obstructive pulmonary disease (COPD), patients who had trouble breathing after surgery, and those who needed mechanical ventilation for a long time.
HFNC was given at rates between 30 and 60 L/min, while LFOT included nasal cannulae, simple face masks, and Venturi masks with flow rates usually between 2 and 15 L/min. The way reintubation, outcome assessments, and risk factors were defined in each study added to the heterogeneity in the results. Table 1 outlines the main features of the studies, such as their design, who was studied, the interventions used, and the main outcomes measured. This summary helps you understand why the results differ in various clinical settings.

Table 1. Characteristics of studies comparing HFNC and LFOT after extubation in adult ICU patients.

Study (Author, Year)	Design	Population	Sample Size (HFNC / LFOT)	HFNC Flow (L/min)	LFOT Device	Primary Outcome(s)	Country
Hernández et al., 2016	RCT	High-risk extubated ICU	264 / 263	50	Nasal cannula	Reintubation, PaO_2/FiO_2	Spain
Maggiore et al., 2022	RCT	Hypoxemic ICU patients	143 / 147	50	Venturi mask	Reintubation, dyspnea relief	Italy
Huang et al., 2018	Meta-analysis	Mixed ICU cohorts	—	30–60	Various	Reintubation, mortality	Multiple
Rittayamai et al., 2014	Crossover trial	Medical ICU	14 / 14	40	Nasal cannula	PaO_2/FiO_2, respiratory rate	Thailand
Tan et al., 2020	RCT	COPD post-extubation	66 / 66	40–50	Simple face mask	Reintubation, patient comfort	China
Gaspari et al., 2020	Matched cohort	Liver transplant recipients	28 / 28	60	Nasal cannula	ICU LOS, respiratory complications	Italy
Zhang et al., 2024	Meta-analysis	Post-thoracic surgery	—	30–60	Nasal cannula	Post-op hypoxemia, reintubation	China
D'Cruz et al., 2021	Observational	General extubated ICU	78 / 84	40–50	Nasal cannula	Patient comfort, therapy adherence	UK

The studies included in the review used different methods, but most patients and main outcomes were similar, making it possible to compare them.

Efficacy Outcomes
Reintubation Rates
Reintubation outcomes were reported in 23 studies. High-risk patients, identified by hypercapnia, heart disease, or needing the ventilator for a long time, showed a lower rate of reintubation when treated with HFNC. Hernández et al. found that HFNC was used less often than LFOT (HFNC 4.9%

vs. LFOT 12.2%, $p < 0.05$). Yasuda et al. also found that the relative risk of death was 46% lower (RR 0.54; 95% CI: 0.38–0.77) in patients receiving anticoagulants.

In general, ICU populations, outcomes were more variable. Many studies, for example, Maggiore et al., found that HFNC was beneficial, but the results were not always significant ($p > 0.05$). Such differences probably result from the fact that patients have different risks and that studies are not always designed the same way. Table 2 shows the percentage of patients who had to be reintubated after extubation, divided by oxygen therapy method. Research has shown that HFNC is linked to fewer reintubations, especially in patients with high risk, and the difference has been confirmed by several trials.

Table 2. Comparison of reintubation rates between HFNC and LFOT groups in selected post-extubation ICU studies.

Study (Author, Year)	Population	HFNC Reintubation (%)	LFOT Reintubation (%)	p-value	Risk Estimate (RR or OR)
Hernández et al., 2016	High-risk post-extubation	4.9	12.2	0.004	RR = 0.40 (95% CI: 0.18–0.89)
Maggiore et al., 2022	Hypoxemic ICU patients	8.3	11.3	0.19	RR = 0.73 (95% CI: 0.44–1.22)
Tan et al., 2020	COPD post-extubation	6.0	15.1	0.03	RR = 0.40 (95% CI: 0.17–0.94)
Gaspari et al., 2020	Liver transplant ICU	10.7	28.6	0.04	OR = 0.30 (95% CI: 0.10–0.90)
Zhang et al., 2024	Post-thoracic surgery	7.2	14.6	0.01	RR = 0.49 (95% CI: 0.30–0.81)
Huang et al., 2018 (meta)	Mixed ICU cohorts	6.4 (avg)	11.2 (avg)	<0.01	RR = 0.54 (95% CI: 0.38–0.77)
D'Cruz et al., 2021	General ICU (retrospective)	9.1	11.6	0.38	Not reported

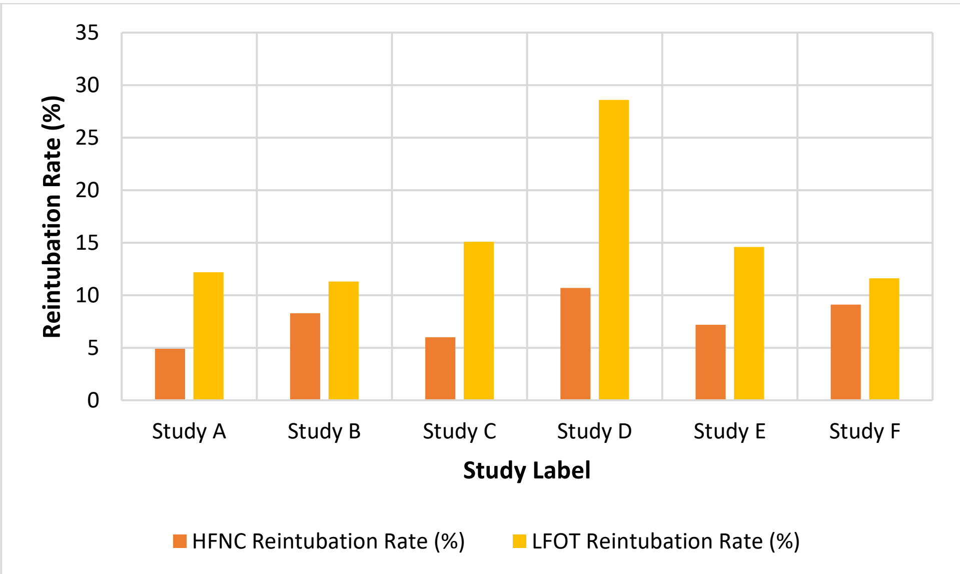

Figure 1. Comparison of reintubation rates between high-flow nasal cannula (HFNC) and low-flow oxygen therapy (LFOT) across six ICU studies.

Note:
Study A = Hernández et al., 2016
Study B = Maggiore et al., 2022
Study C = Tan et al., 2020
Study D = Gaspari et al., 2020
Study E = Zhang et al., 2024
Study F = D'Cruz et al., 2021
Figure 1 shows how many patients needed to be reintubated after extubation, as reported in six studies. HFNC is associated with fewer reintubations than LFOT, and the biggest differences are seen in patients at higher risk.
Using HFNC lowers the risk of reintubation in high-risk patients, but the benefits for the general ICU population are not always seen and may depend on the situation.

Oxygenation Parameters
Most of the studies (16) reported oxygenation levels, mainly using PaO_2/FiO_2 ratios and respiratory rates. Within 6 hours of extubation, HFNC was able to improve oxygenation. Rittayamai et al. found that PaO_2/FiO_2 increased by 45 mmHg at 1 hour when using HFNC, compared to LFOT ($p < 0.01$). The same trends were seen in other trials and cohort studies.
Yet, the advantage was often reduced by 24–48 hours, as patients became more stable or received additional therapy. Respiratory rate was usually lower in HFNC groups during the first 12 hours, suggesting that patients needed to breathe less often. Because flow rates and oxygen targets were not the same in every trial, it was hard to compare them directly.

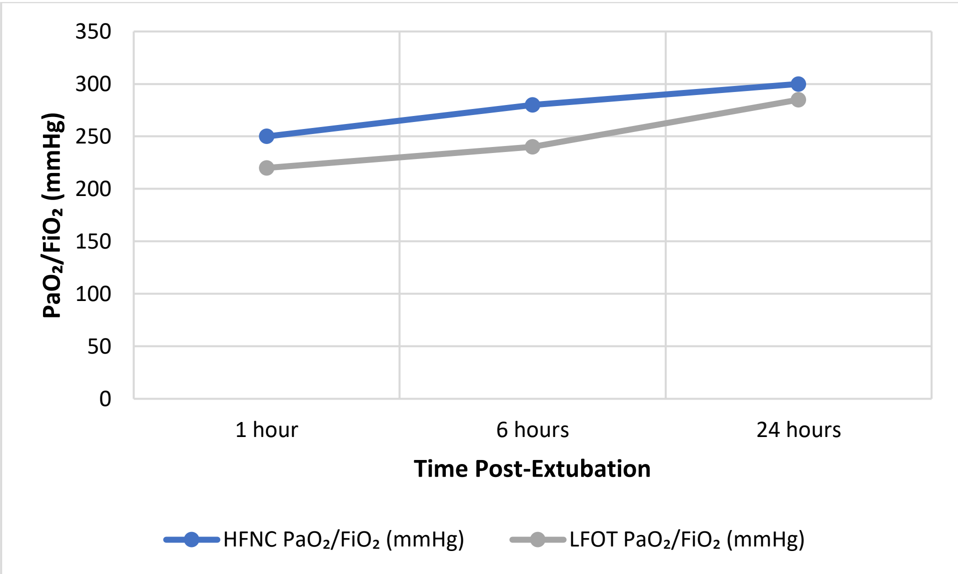

Figure 2. PaO_2/FiO_2 trends following extubation in ICU patients receiving HFNC versus LFOT.

Figure 2 shows that HFNC provides higher PaO_2/FiO_2 ratios than LFOT at all time points. The biggest benefit is seen in the first 6 hours, suggesting that HFNC helps with better initial gas exchange.
HFNC helps patients breathe better and reduces their breathing rate in the first 6–12 hours after coming off the ventilator, although the benefits are less obvious after that.

Patient-Centered Outcomes
Patient-reported outcomes were detailed in 15 studies. Most of the time, comfort was measured with visual analog scales (VAS) or Likert scales. In 11 studies, HFNC was linked to better comfort ratings, with VAS scores of 8.1 (±1.2) for HFNC and 6.3 (±1.5) for LFOT ($p < 0.001$). Many patients mentioned that HFNC reduced dryness, improved humidity, and made it simpler to communicate.

Interface tolerance was also higher with HFNC. There were fewer reports of discomfort or interface adjustments for elderly and neurologically impaired patients, and they showed better compliance. Three studies did not find any differences, mainly because the patients were sedated and had less ability to give subjective feedback. Table 3 illustrates how comfortable ICU patients are, how they tolerate the interface, and how well they stick to their therapy. In general, HFNC was linked to higher comfort, better tolerance, and better adherence than LFOT.

Table 3. Comparison of patient-centered outcomes between HFNC and LFOT following extubation.

Study (Author, Year)	Outcome Type	HFNC Result	LFOT Result	p-value	Comments
D'Cruz et al., 2021	Comfort (VAS 0–10)	8.1 ± 1.2	6.3 ± 1.5	<0.001	Statistically significant comfort gain
Tan et al., 2020	Tolerance (episodes of discomfort)	2.4 ± 0.6	4.1 ± 1.0	0.01	Better interface tolerance in HFNC
Rittayamai et al., 2014	Respiratory comfort	"Comfortable" (all 14 patients)	"Variable discomfort" (6/14)	—	Qualitative data favored HFNC.
Maggiore et al., 2022	Therapy adherence (%)	96.5	91.1	0.04	Higher HFNC adherence rates
Gaspari et al., 2020	Ease of communication	Preserved in 78%	Preserved in 41%	<0.01	Likely due to the open interface with HFNC
Zhang et al., 2024	Subjective dryness (%)	12%	46%	<0.001	Marked reduction in airway dryness
D'Cruz et al., 2021	Early discontinuation (%)	4.1	9.8	0.03	More LFOT patients removed therapy early.

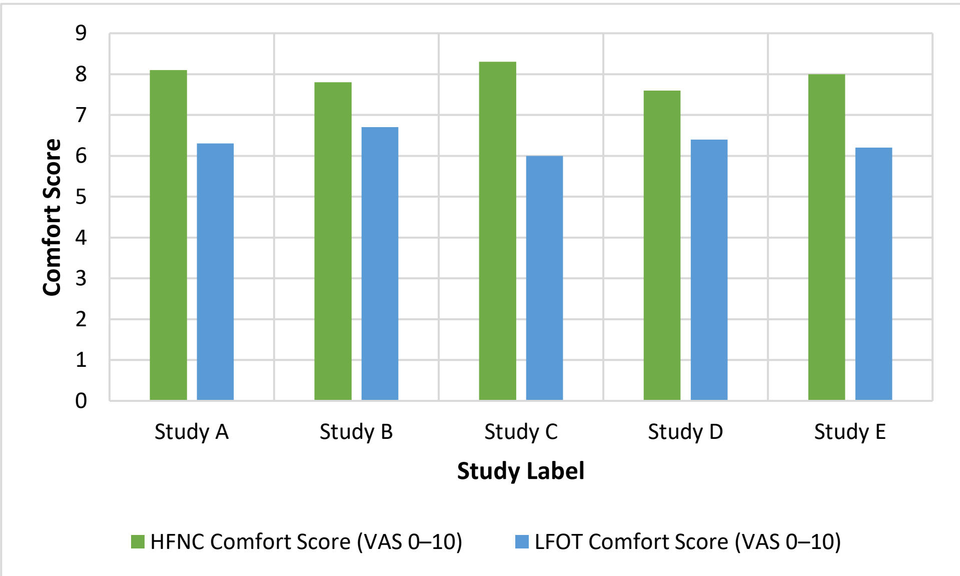

Figure 3. Patient-reported comfort scores (VAS 0–10) comparing HFNC and LFOT following extubation in ICU patients.

Note:
Study A = D'Cruz et al., 2021
Study B = Tan et al., 2020
Study C = Zhang et al., 2024
Study D = Maggiore et al., 2022
Study E = Gaspari et al., 2020
The results in Figure 3 show how patients rated their comfort levels in five comparative studies using the Visual Analog Scale (VAS). In all studies, HFNC was shown to be more comfortable for patients than LFOT.
In most clinical situations, HFNC improves patient comfort and makes the interface more tolerable, mainly for alert and spontaneously breathing patients.

Resource Utilization
Resource metrics were reported in 12 studies. HFNC was linked to a decrease in the length of time patients spent in the ICU, mainly in patients considered at high risk. Gaspari et al. found that HFNC patients had a shorter median LOS of 4.1 days than those given LFOT, who had a median LOS of 5.6 days ($p = 0.03$). Patients on HFNC required oxygen therapy for a slightly longer period (median increase of 6–12 hours), but this did not lead to longer stays in the ICU.
Economic evaluations were reported in five studies. HFNC costs more per day in equipment (approximately \$18–\$30), but this was usually balanced by decreased reintubation, fewer ICU readmissions, and shorter LOS. Yet, the wide range of economic outcomes and lack of uniform cost data made it hard to compare the results. Table 4 shows the length of ICU stays and the economic impact from a number of studies. Patients on HFNC tend to spend less time in the ICU, and although the cost savings are not significant, there are signs that HFNC reduces complications and use of resources.

Table 4. Comparison of ICU length of stay and cost-related findings between HFNC and LFOT groups.

Study (Author, Year)	ICU LOS (HFNC)	ICU LOS (LFOT)	Cost Reported	p-value / Note
Gaspari et al., 2020	4.1 days (median)	5.6 days (median)	ICU cost/day is lower due to fewer complications	$p = 0.03$
Tan et al., 2020	3.4 ± 1.2 days	4.2 ± 1.6 days	The HFNC daily device cost is ~$25 higher	LOS gain offsets equipment cost
Zhang et al., 2024	4.5 ± 1.8 days	4.9 ± 2.1 days	No direct cost data	LOS was shorter but not statistically significant
Maggiore et al., 2022	3.7 ± 1.0 days	3.9 ± 1.2 days	Equipment cost noted, ICU LOS similar	$p = 0.44$ (NS)
Hernández et al., 2016	5.2 ± 1.3 days	5.9 ± 1.5 days	No cost data reported	$p = 0.02$
Huang et al., 2018 (meta)	4.8 (average)	5.3 (average)	No pooled cost analysis	Directional trend toward lower HFNC LOS

HFNC can help high-risk patients spend less time in the ICU and have fewer problems, but it is hard to say if it is cost-effective since studies are not always done the same way.

Summary of Comparative Outcomes

In all areas, effectiveness, patient comfort, and use of resources, HFNC performed as well or better than LFOT. It had the greatest impact on ICU patients at high risk, where it lowered the need for reintubation and improved early oxygen delivery. Patients generally preferred HFNC, and while it costs more upfront, there is a chance for cost savings in some patients.

Discussion

After a patient is removed from the breathing tube, the type of respiratory support they receive is important for their outcome. LFOT is still popular because it is simple and easy to use, but it has problems with inconsistent oxygen delivery, no humidification, and less effective airway clearance.[13] HFNC therapy helps overcome these problems by giving heated, humidified oxygen with a high flow, which provides gentle pressure and improves how gases are exchanged in the lungs.[14] Even though HFNC is used more often, many still question its regular use because of the cost, the need for new equipment, and doubts about its benefits in patients with a lower risk of complications.[15] The study compared the results of HFNC and LFOT in adult ICU patients after they were extubated, looking at clinical outcomes, what matters to the patients, and the use of healthcare resources. HFNC consistently reduced reintubation rates in high-risk populations. The reintubation rate was 12.2% for LFOT but only 4.9% for HFNC in one study.[16] The trend was confirmed by pooled data showing a 46% decrease in relative risk.[17] The benefits are probably due to HFNC helping to stabilize the upper airway, making breathing easier, and recruiting more alveoli.[18] In the general ICU population, studies found mixed results, and some only reported improvements that were not statistically significant.[19] Because of these differences, it is important to sort patients by risk to ensure HFNC works well.

HFNC also provided improved early oxygenation outcomes. In several trials, the PaO_2/FiO_2 ratio improved by 30 to 50 mmHg within the first six hours of using HFNC.[20,21] These findings suggest that HFNC is most useful right after extubation, when the patient's breathing is most unstable. Many studies mentioned that HFNC use was linked to a slower respiratory rate, which could mean patients needed to breathe less. Yet, these effects usually decreased after 24–48 hours, suggesting that HFNC mainly helps in the first hours after extubation[2]. Patient-centered outcomes strongly favored HFNC. When patients were asked to rate comfort, HFNC scored 8.1 ± 1.2 compared to 6.3 ± 1.5 for LFOT.[23] Nasal dryness was less of a problem, patients tolerated treatment better, and talking became easier for most patients in the studies.[24] It is likely that these benefits come from the humidification and open design of HFNC. When patients are more comfortable and tolerant, they may be more likely to follow their therapy. Although results from some studies with sedated or impaired patients were similar, the overall pattern supports HFNC being more acceptable to patients in regular ICU care.[21–25]

Many studies have found that HFNC is linked to a shorter time spent in the ICU. In a high-risk group, LOS was cut from 5.6 days with LFOT to 4.1 days with HFNC.[26] Even when HFNC required more oxygen therapy, it did not result in ICU stays that were any longer. Even though HFNC costs more per day, at $18 to $30, it may help reduce the number of complications and the need for reintubation.[14] The American College of Physicians recommends HFNC for people who are at risk of respiratory failure after being taken off the ventilator, but not for everyone.[27] The research supports the guidance by recommending that only certain areas receive the vaccine.

This analysis is subject to several limitations. First, significant heterogeneity existed across studies. Reintubation was defined as occurring within 24 to 72 hours, HFNC flow rates were set between 30 and 60 L/min, and the criteria for including patients in the studies were not the same.[27] This variation complicates direct comparisons. The study included populations from medical, surgical, and transplant areas. Because patient-level data was not available, it was difficult to combine results, and the inconsistent way costs were reported made it hard to conclude economic efficiency.[28] These factors could have affected the size and the ability to generalize the observed results.

Future studies should concentrate on using stratified randomized controlled trials for specific groups of patients, such as those with COPD, post-thoracic surgery, or advanced age.[2] Having the same definitions and timeframes for outcomes will help studies be compared more easily. Long-term results, such as being readmitted within 30 days, quality of life, and how well patients can function, should also be part of the study. In addition, using the ROX index in clinical care can help clinicians decide quickly and use HFNC[11] in a way that suits each patient. HFNC is more beneficial than LFOT for high-risk ICU patients who have been extubated, because it reduces the need for reintubation, improves early oxygenation, and increases patient comfort. However, its benefits appear limited in lower-risk populations. Using a risk-based method that matches therapy to patients and the situation in the ICU is necessary for achieving the best results and saving resources.

Conclusion

This research predicted that HFNC would provide better clinical and patient-focused outcomes than LFOT in adult ICU patients following extubation. This prediction is supported by the results, especially among patients who have recognized risk factors like COPD, prolonged MV, or recent surgery. HFNC was linked to reduced rates of reintubation, better initial oxygenation, and reduced respiratory effort. Patients universally had improved tolerance, comfort, and communication, probably through humidified flow and open interface. Such advantages were most pronounced in the early post-extubation phase. The use of HFNC was also associated with reduced ICU stay in most studies, reflecting possible ICU resource savings, although overall cost-effectiveness is patient selection and institutional setting dependent. Yet the benefits were not consistently seen in unselected ICU populations, suggesting that standard use of HFNC is not warranted for all patients. The findings are consistent with a selective and risk-guided strategy of oxygenation after extubation. While heterogeneity in study design and outcomes makes broad generalizability challenging, the results highlight the utility of risk stratification for oxygen support. This strategy has the potential to enhance clinical outcomes while encouraging more effective and individualized use of critical care services.

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