Indian Journal of Clinical Anaesthesia 2025;12(1):125–131

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Indian Journal of Clinical Anaesthesia

Journal homepage: www.ijca.in

Original Research Article

Comparison of high flow nasal cannula and conventional oxygen therapy post-extubation in intensive care unit: A prospective crossover observational study

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ARTICLE INFO

Article history:
Received 15-07-2024
Accepted 23-12-2024
Available online 20-01-2025

Keywords:
High flow nasal oxygen
Venturi mask
Post-extubation oxygenation
ABG analysis
Dyspnea score

ABSTRACT

Background: Post-extubation respiratory support is crucial for optimal recovery and preventing reintubation in intensive care unit (ICU) patients. High Flow Nasal Oxygen (HFNO) has emerged as an effective alternative to conventional oxygen therapy (COT) for maintaining oxygenation and improving patient outcomes after extubation. This study aimed to compare the effects of HFNO and conventional oxygen therapy on dyspnea scores, arterial blood gas (ABG) parameters, physiological variables such as respiratory rate (RR), heart rate (HR), blood pressure, and patient comfort.

Materials and Methods: ICU patients who were mechanically ventilated, ready for extubation, and had successfully completed a Spontaneous Breathing Trial (SBT) were enrolled. Participants were divided into two groups: Group A received HFNO for the first 30 minutes after extubation, followed by a Venturi Mask (VM) for the next 30 minutes. Group B received a VM immediately after extubation, followed by HFNO. Dyspnea scores were assessed using a visual analogue scale, and HR, Mean Arterial Pressure (MAP), RR, Oxygen Saturation (SpO_2), and ABG parameters were recorded and compared between the two groups.

Results: Baseline hemodynamic parameters, intubation time, and comorbidities were similar between the groups (p = 0.325). Both groups showed a significant improvement in dyspnea scores with HFNO (Group A: from 34.6 to 16.4, Group B: from 33 to 19.1). HR, MAP, RR, and SpO_2 remained stable with both HFNO and VM, while HFNO slightly improved the Partial Pressure of Oxygen (from 154 to 177.3). Patient comfort was significantly higher with HFNO compared to VM (p = 0.003).

Conclusion: HFNO is more effective in reducing dyspnea and improving patient comfort post-extubation compared to conventional oxygen therapy, without affecting vital signs such as heart rate and respiratory rate. This suggests that HFNO is a promising modality for post-extubation oxygenation in ICU patients.

1. Introduction

Adequate oxygen supply plays a significant role in the management of patients after endotracheal extubation.[1] A routinely used venturi face mask can deliver 100% oxygen at maximum flow rate of 10-15 liters/min.[2] In a few patients, if there is a high inspiratory flow demand (30 l/min-120 l/min), then the venturi mask may be insufficient in delivering the required oxygen. This might lead to extubation failure necessitating re-intubation again in ventilated critically ill patients.[3] Several oxygen delivery modes and techniques have been used to decrease the extubation failure rate and support freshly weaned patients, including noninvasive ventilation.[4]

High-flow nasal oxygen (HFNO) is a recent advanced technological device that delivers fully humidified, high-flow oxygen (up to 60 l/min) with a constant fraction of inspiratory oxygen and flow-dependent continuous positive

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https://doi.org/10.18231/j.ijca.2025.019

airway pressure.[5] HFNO's clinical advantages include improved oxygenation, decreased respiratory secretions, increased end-expiratory lung volume, and reduced work of breathing.[6] An air O_2 blender used in HFNO produces an airflow of 55 l/min while allowing the fraction of oxygen (FiO_2) to range from 0.21 to 1.00. This process could perhaps wash out dead pharyngeal space and decrease nasopharyngeal resistance.[7] Extubated patients need a high inspiratory flow and adequate oxygen. HFNO can play a significant role in delivering adequate oxygen and preventing chances of reintubation.[8,9] However, there is limited data in the medical literature on the advantages of short-term high-flow nasal oxygenation post-extubation.

This study was conducted to determine the effectiveness of HFNO post-extubation, with various parameters such as dyspnea score, arterial blood gas analysis, and patient comfort being reviewed and compared. The study aimed to compare the effectiveness of conventional oxygen therapy and HFNO in the intensive care unit post-endotracheal extubation. The primary objective was to compare the two modes of oxygenation in terms of changes in dyspnea score after extubation. The secondary objectives were to compare the changes in arterial blood gas analysis, physiological variables like respiratory rate, blood pressure, and heart rate, as well as patient comfort.

2. Materials and Methods

This crossover single-blind observational study was conducted in a tertiary care ICU from April 2021 to September 2022. All critically ill, intubated patients aged over 18 years, who met extubation criteria and were eligible for extubation in the intensive care unit, were included in the study. Participants with a Glasgow Coma Scale (GCS) score of less than 8, uncooperative participants, pregnant women, individuals with facio-maxillary deformities, and those with neuromuscular diseases were excluded from the study.

The sample size was calculated based on a study by Rittayamai.[10] which reported a standard deviation (SD) of 1.2 for the dyspnea score in both groups A and B. Assuming an effect size of 0.963, a study power of 95%, and an alpha error of 5%, the required sample size was determined to be 22, with 11 participants in each group. This calculation was done using n-Master version 2 software. Due to the small sample size, patient randomization was not performed.

After approval of the Institutional Ethics Committee (INST.EC/EC/054/2021-22), the participants satisfying inclusion criteria, without extubation criteria, were enrolled after obtaining consent from the patient's attendant. Participants who accomplished the Spontaneous Breathing Trial (SBT) satisfactorily were considered for tracheal extubation. In general, participants with stable hemodynamic parameters and sufficient oxygenation were weaned using SBT for 120 minutes while using an oxygen T-piece or low-level pressure assistance. Criteria for extubation: 1) Adequate oxygenation (SpO2 > 92%, PaO_2 > 60 mmHg). 2) Adequate ventilation (tidal volume> 5 ml/kg, spontaneous respiratory rate >7 breaths per minute, end tidal carbon dioxide < 50 mm Hg, $PaCO_2$ < 60 mm Hg). 3) Hemodynamically stable. 4) Complete reversal of muscle relaxant (sustained tetany, train of four (TOF) > 0.9, sustained head lift for more than five seconds). 5) GCS score (follows verbal commands, and intact cough/gag reflex).

Demographic data and baseline clinical data were collected before endotracheal extubation. After successful endotracheal extubation, participants were divided into two groups as per the concerned intensivist on duty. Participants were educated about the procedure and visual analogue scale for dyspnoea.

In group A, Oxygenation was administered using HFNC with a 35 l/min starting inspiratory flow, and to obtain a SpO_2 of at least 95% during the initial five minutes and to sustain these parameters for 30 minutes and FiO_2 was modified accordingly. Followed by a venturi face mask at 10 l/min to achieve SpO_2 - 95% for another 30 min. We used an initial flow of 35 l/min via HFNC and a research duration of 30 minutes with each intervention.

In Group B, the participants were started with a Venturi face mask at 10 l/min to achieve an SpO_2 of 95% for 30 minutes. They were then switched to HFNC at 35 l/min to maintain an SpO_2 of 95% for the next 30 minutes. Following extubation, dyspnea and participant comfort were assessed using a Visual Analogue Scale (VAS) score (ranging from 0 to 10) immediately and during each mode of oxygenation. The score was determined by measuring the distance in millimeters (mm) on a 10-centimeter (cm) line between the "no breathlessness" anchor and the patient's mark using a ruler, providing a range of scores from 0 to 100. Immediately upon extubation, and at 5, 10, 15, and 30 minutes into each intervention session, the respiratory rate (RR), heart rate (HR), mean arterial pressure (MAP), and SpO_2 were measured.

At the conclusion of the study, the participants were asked if they preferred HFNC or the Venturi face mask. Pre-extubation, half an hour after the first intervention, and at the end of one hour, arterial blood gas (ABG) parameters were recorded. The critical care physician adjusted both the type and quantity of oxygen supply as needed after one hour (the end of the study).

Participants indicated their level of dyspnea by marking on the line. The VAS was used to evaluate the trend of dyspnea in the same patient over time. An interval of scores from 0 to 100 was obtained by measuring the distance (mm) on the 10-cm line between the "no breathlessness" anchor and the patient's mark using a ruler.

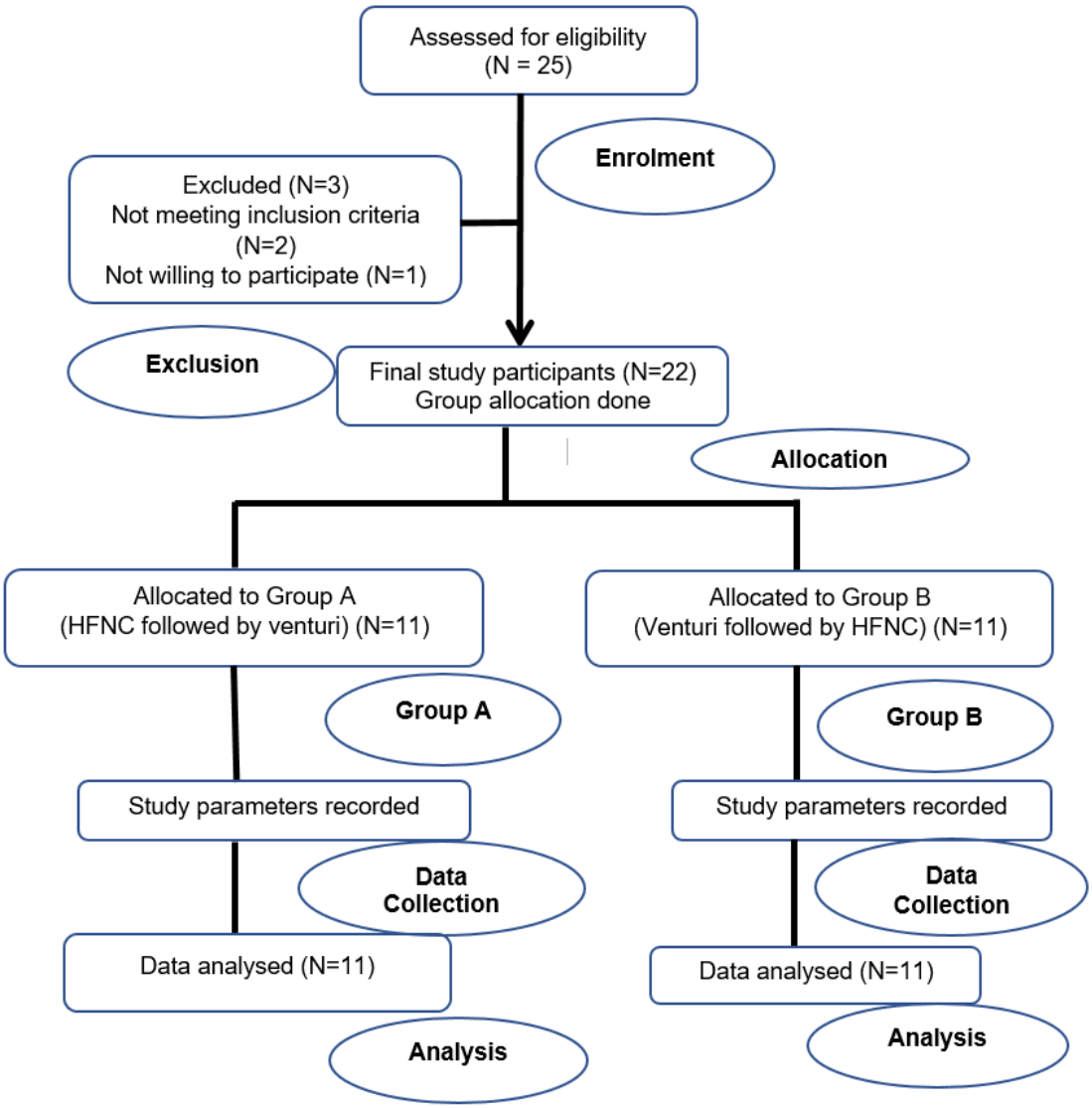


Diagram 1: Diagram of participants

2.1. Statistical analysis

Qualitative variables were analysed using Chi-square test and presented using frequency or percentages. The quantitative variables were analysed using Unpaired Student's T test or Mann-Whitney U test and were presented using mean, SD and confidence interval. $P < 0.05$ was considered statistically significant.

3. Result

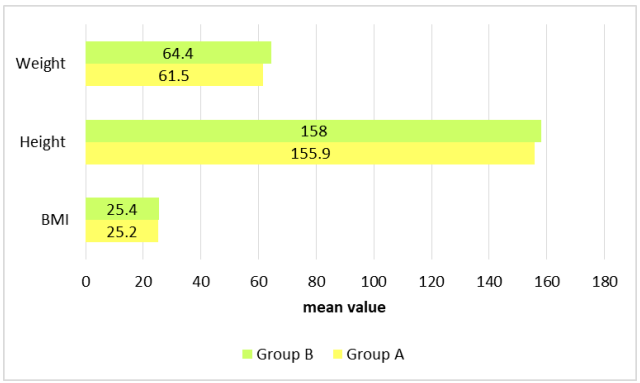
The average age in groups A and B were 60.4 ± 12.6 and 50.7 ± 14.7 years, respectively. Both groups were compared in terms of age using the Mann-Whitney Test, demonstrating that the difference is statistically nonsignificant with a p-value of 0.116. Hence, the two groups were comparable in terms of age. In group A, most participants were above 60 years, and in group B, most participants were between 40 and 60 years. A comparison of age groups between group A and group B was made; it is statistically insignificant, with a p-value of 0.325. As a result, the distribution of participants in the different age groups seemed comparable across the groups. The two groups were comparable in terms of gender and there was no statistically significant difference between the groups, with a p-value of 0.670 (Table 1).

The difference between the two groups in terms of weight, height, and body mass index (BMI) were statistically nonsignificant, with a p-value of 0.401 for weight, 0.760 for height, and 0.699 for BMI. Average weight, height, and BMI were comparable between groups A and B (Graph 1).

Table 1: Comparison of participant's ages between group A and group B

Parameters	Group A N (%)	Group B N (%)	p-value*
Age group			
21 to 40 years	01 (9.1%)	03(27.3%)	0.550
41 to 60 years	04(36.4%)	05(45.5%)	
> 60 years	06(54.5%)	03(27.3%)	
Gender			
Male	06 (54.5%)	05 (45.5%)	0.670
Female	05 (45.5%)	06 (54.5%)	
Comorbidities			
Respiratory Cardiovascular	3 (27.3)	3 (27.3)	1.000
Chronic kidney disease	3 (27.3)	1(9.1)	0.586
	0	1(9.1)	0.586

*p-value is calculated by Chi-square test



Graph 1: Comparison of groups based on average weight, height, and BMI

Participants with respiratory comorbidity are equally distributed between the groups. Group A distribution participants were associated more with cardiac comorbidities than group B (Table 1).

The majority of participants from group A were intubated for 2 days and most participants from group B were intubated for 1day.

As shown in Table 2, the comparison of baseline mean heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), respiratory rate (RR), mean arterial pressure (MAP), and SpO2 between the two groups did not show any statistically significant difference between the groups. The p-value is not less than 0.05; hence the baseline mean hemodynamic parameters between the groups were comparable.

Mean dyspnea scores were compared; immediately after extubation, the mean score was 34.6 mm and 33.6 mm in groups A and B, respectively and a p-value of 0.847. Hence both the group's participants were comparable in terms of dyspnea score before the different modes of oxygenation. At the end of the first intervention, the mean dyspnea score of group A (16.4 mm) was slightly better (2.7 mm) than group B (19.1) but was statistically insignificant. At the end of the second intervention, the dyspnea score of group B (11.6) was better compared to group A (19.1) (Table 3). The mean dyspnea score in group A improved from 34.6 to 16.4 at the end of first intervention (HFNC) and slightly deteriorated at the end of the second intervention (venturi mask) but was statistically insignificant. The dyspnea score in group B improved to 19.1 from 33 at the end of the first intervention and further improved to 11.8 by the end of the second intervention. In group A, the dyspnea score improved from the baseline, but slight deterioration was noted by the end of second intervention. Whereas in group B, there was a gradual improvement in dyspnea score from the baseline (Table 3).

After extubation, a comparison of mean heart rate, mean arterial pressure, respiratory rate, and oxygen saturation change at the different time intervals between groups A and B showed statistically nonsignificant (Table 4).

In both groups, there was no variation in pH, even with minimal variation in $paCO_2$. The variation in pH values of both groups at different modes of oxygenation was noted in the above table and was not statistically significant, with a p-value>0.05 (Table 5).

The partial pressure of oxygen (paO_2) level in group A, improved from 154 mmHg to 177.3 mmHg after first mode of oxygen (HFNC), which is statistically significant with p value < 0.001, paO_2 level slightly decreased to 165 mmHg after second mode of oxygenation (venturi mask). Whereas, in group B, the paO_2 level improved from 150.8 mmHg to 160 mmHg after the first mode of oxygenation (venturi mask) and the paO_2 level further improved to 165.8 mmHg after second mode of oxygenation (HFNC). Nevertheless, the improvement was not significant clinically (Table 6).

Immediately after extubation, $paCO_2$ levels between the two groups were comparable with a p-value of 0.386. At the end of first intervention, there was a decrease in $paCO_2$ levels in both groups, which was statistically significant, but there was no clinical significance. At the end of the second intervention, $paCO_2$ remained within the normal range between the two groups (Table 6).

Table 2: Baseline hemodynamic parameters between group A and group B

Baseline hemodynamic parameters	Group A Mean value ± SD	Group B Mean value ± SD	p -value*
HR (in BPM)	85.8±12.3	85.8±10.9	0.668
SBP (in mmHg)	127.3±9	124±16.1	0.614
DBP (in mmHg)	81.8±10.8	76.4±10.3	0.211
MAP (in mmHg)	95.4±11.1	91.7±10.3	0.510
RR (in CPM)	14.6±0.6	14±1	0.830
SpO_2 (in %)	96±2.9	97.1±3.1	0.350

*p-value is calculated by Unpaired t-test

Table 3: Mean dyspnea score between Group A and Group B

Mean Dyspnea	Group A Mean± SD	Group B Mean ±SD	P-value*
After Extubation	34.6± 8.2	33.6 ±9.2	0.847
At 30 min	16.4 ±6.7	19.1± 7	0.348
At 60 min	19.1±11.6	11.8 ±4	0.102

*p-value is calculated by Unpaired t-test

Table 4: Comparison of hemodynamic parameters after extubation in Group A and Group B

Hemodynamic Parameters	Group A	Group B	P- Value*
Mean Heart Rate (in bpm)			
At 0 min	97.5	100.9	0.184
At 30 min	87.1	90.0	0.121
At 60 min	88.4	89.0	0.792
Mean Arterial Pressure (in mmHg)			
At 0 min	85.3	84.5	0.645
At 30 min	82.9	83.3	0.869
At 60 min	83	83	0.987
Respiratory Rate (in CPM)			
At 0 min	16.7	16.3	0.635
At 30 min	14.2	14.6	0.206
At 60 min	14.8	14.3	0.310
SpO2 (in %)			
At 0 min	96.6	97.6	0.343
At 30 min	98.9	99.2	0.857
At 60 min	98.4	99.3	0.058

*p-value is calculated by Unpaired t-test

Table 5: pH analysis between and within the group

Time	Group AMean ±SD	Group BMean ±SD	p-value*
Before extubation	7.39±0.02	7.38±0.02	0.199
At the end of first intervention	7.38±0.02	7.39±0.02	0.739
At the end of second intervention	7.39±0.02	7.38±0.02	0.071

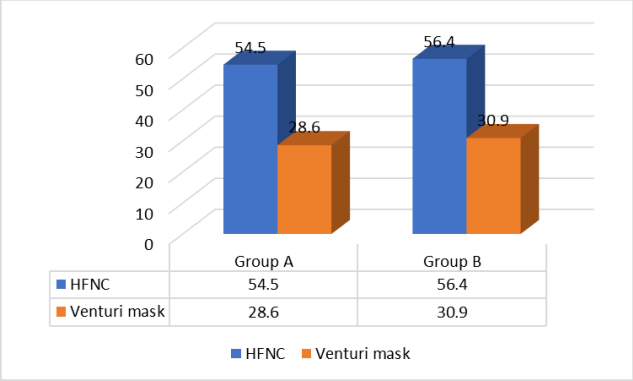
*p-value is calculated by Unpaired t-test

Table 6: Comparison of Group A and Group B according to the paO_2 and $paCO_2$

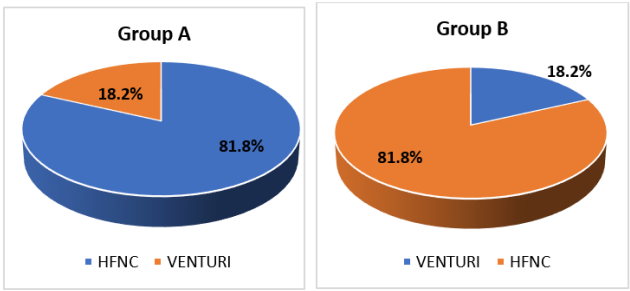
Parameter	Immediately after extubation	At the end of the first intervention	At the end of the second intervention
Partial pressure of O_2 levels	154±18.9	177.3±21.1	165.3±19.4
Group A			
Group B	150.8±11.2	160.2±12.5	165.8±9.6
p- value*	0.510	0.066	0.645
Partial pressure of CO_2 levels			
Group A	38.6±2.6	35.8±1.9	37.9±2.2
Group B	37.8±1.8	38.6±2.3	37.0±1.7
p-value*	0.386	0.007	0.322

*p-value is calculated by Unpaired t-test

In group A, patient comfort was better with first mode of oxygen delivery (HFNC) with a VAS score of 28.6 mm compared to a VAS score of 54.5 mm with second mode of intervention (venturi) with a significant p value of 0.016. In group B, patient comfort was better with the second mode of intervention, with a VAS score of 30.9 mm compared to a VAS score of 56.4 mm during first mode of intervention (Graph 2). In group A, 81% of participants were comfortable with first intervention (HFNC), and in group B, 81.8% of participants were comfortable with second intervention (HFNC), this was significant statistically with a P value of 0.003 (Graph 3).



Graph 2: The patient comfort using VAS score (in mm) between the groups



Graph 3: Patient preference between HFNC and venturi

4. Discussion

In the present study, we found that high-flow nasal cannula (HFNC) significantly enhanced patient comfort and reduced dyspnea after extubation compared to Venturi mask oxygen therapy. While there was a minimal improvement in the dyspnea score, patient comfort showed a notable improvement with HFNC.

In Group A (HFNC), after the first intervention (30 minutes), there was a 49.4% improvement in the dyspnea score, whereas Group B (Venturi mask) showed a 42.3% improvement. After the second intervention at 60 minutes, when Group A patients were switched to the Venturi mask, their dyspnea score worsened by 12%. Conversely, in Group B, which received HFNC as the second intervention, the dyspnea score improved further by 33%.

Corley et al. found similar results in their study, where 155 patients who underwent cardiac surgery and received HFNC post-extubation showed a lower dyspnea score.[11] Similarly, Rittayamai et al. studied 17 subjects with respiratory failure and found that those who received HFNC immediately post-extubation had a significantly lower dyspnea score ($p = 0.04$) compared to those receiving a non-rebreathing face mask, mirroring the results of our study.[10]

In contrast to the improvement in comfort and dyspnea, we observed no significant changes in respiratory rate (RR) and oxygen saturation (SpO_2), which contradicts findings by Basak Akyildiz et al., who included 100 pediatric patients and reported improved oxygen saturation, heart rate (HR), and RR during the first hour of HFNC administration, with these improvements persisting up to 48 hours.[12] This discrepancy may be attributed to differences in patient populations and clinical settings.

Our study also revealed a relative improvement in PaO_2 during HFNC administration compared to the Venturi mask in both groups. However, $PaCO_2$ levels decreased slightly after HFNC administration in both groups, but this reduction was not clinically significant. In contrast, Tan et al. observed that in their study comparing HFNC and non-invasive ventilation (NIV) post-extubation, the HFNC group exhibited lower pH and PaO_2/FiO_2 values and higher $PaCO_2$ levels after one hour, indicating varying results in different clinical contexts.[13]

Similar findings were reported by Maggiore et al., who studied 105 patients and found that post-extubation HFNC was associated with better patient comfort and fewer instances of desaturation compared to the Venturi mask.[14] Sang et al. also noted excellent comfort and interface tolerance with HFNC in their study of 19 participants post-extubation. In our study, 81% of participants in both groups preferred HFNC over the Venturi face mask, suggesting better tolerance of HFNC, likely due to the soft and pliable nasal prongs.[15]

The results of this study highlights the potential benefits of HFNC in post-extubation care, particularly in improving patient comfort and reducing dyspnea. The ability to deliver a high flow of oxygen through a non-invasive method, combined with the soft nasal prongs, contributes to its patient-friendly nature, which enhances its acceptance compared to more invasive methods like the Venturi mask. Given the increasing importance of improving patient experience and reducing complications related to oxygen therapy, HFNC presents a promising approach in the post-extubation setting. However, further large-scale studies are necessary to validate these findings and assess the long-term

outcomes of HFNC use across diverse patient populations.

Limitations of the study include the absence of a washout period in the protocol before implementing each intervention, which could have introduced bias, particularly in respiratory rate, partial pressure of oxygen (PaO_2), and carbon dioxide ($PaCO_2$) levels. The lack of randomization, due to the small sample size, might have affected the baseline characteristics of the participants. Additionally, this study did not measure the PaO_2/FiO_2 ratio, which could have provided a clearer picture of the improvement in oxygenation status. The impact of HFNC on sputum production or expectoration was also not assessed. Furthermore, the physiological differences between HFNC and traditional oxygen therapy may not have been fully discernible within 30 minutes of HFNC exposure, and a longer exposure or cough assessment might have highlighted differences in patient comfort more distinctly. Moreover, HFNC is a more expensive mode of oxygenation and is not universally available across all clinical settings.

The implications of the study suggest that HFNC is associated with lower dyspnea scores and improved patient comfort, making it a safe and effective option for preventing respiratory failure after extubation. The study also raises awareness about the benefits of HFNC, which can be utilized to manage critically ill patients, especially during pandemics. This research provides direct comparative evidence on the efficacy and outcomes of HFNC versus conventional oxygen therapy (COT) in post-extubation ICU patients. It fills a critical gap in the literature regarding post-extubation respiratory management. The study highlights the importance of patient comfort, tolerance, and respiratory support requirements, which are essential for optimizing post-extubation recovery and improving ICU practices.

5. Conclusion

Compared to Venturi mask oxygen therapy, HFNC can significantly enhance patient comfort and reduce dyspnea following extubation. While the improvement in the dyspnea score may not be significant, the marked increase in patient comfort highlights the benefits of HFNC. This mode of oxygenation may prove to be a valuable tool in preventing post-extubation hypoxemia, offering a non-invasive, more comfortable alternative to traditional oxygen therapies.

6. Source of Funding

None.

7. Conflict of Interest

The authors declare no conflict of interest.

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Cite this article: Shetty A, Kintamani GP, Bhat GM. Comparison of high flow nasal cannula and conventional oxygen therapy post-extubation in intensive care unit: A prospective crossover observational study. *Indian J Clin Anaesth* 2025;12(1):125-131.