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High flow nasal cannula oxygen therapy versus bilevel positive airway pressure as a mode of oxygen delivery a prospective observational study in patients with pneumonia and hypoxemic respiratory failure

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ABSTRACT

Background: High-flow nasal cannula (HFNC) and bilevel positive airway pressure (BiPAP) are common non-invasive ventilation strategies, but their comparative effectiveness in oxygenation and patient outcomes remains under investigation. **Aims and Objectives:** This study compares the efficacy of HFNC and BiPAP in patients with pneumonia and hypoxemic respiratory failure (HRF). **Materials and Methods:** Patients with pneumonia and HRF admitted to the intensive care unit or emergency department were assigned to either HFNC or BiPAP based on clinical judgment. Outcomes assessed included oxygenation (PaO_2/FiO_2), respiratory rate, patient comfort, intubation rates, hospital stay length, and survival. **Results:** HFNC and BiPAP showed similar short-term oxygenation improvements. HFNC provided better comfort and ease of use, while BiPAP offered superior ventilation support and respiratory rate reduction. Both methods had comparable intubation rates and hospital stay lengths, though BiPAP may benefit patients with severe distress. **Conclusion:** HFNC improved oxygenation and shortened hospital stays, while BiPAP enhanced ventilation. Mortality rates were similar, suggesting both can be used in managing mild acute respiratory distress syndrome, depending on patient needs and available resources.

Key words: High-flow nasal cannula; Bilevel positive airway pressure; Oxygen therapy; Pneumonia; Hypoxemic respiratory failure; Non-invasive ventilation; Patient outcomes

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INTRODUCTION

Pneumonia is a leading cause of morbidity and mortality worldwide, particularly in vulnerable populations such as the elderly, immunocompromised individuals, and those with pre-existing respiratory conditions. It is characterized by inflammation of the alveoli, which may be filled with fluid or pus, leading to impaired gas exchange and subsequent respiratory distress. The condition often progresses to hypoxemic respiratory failure (HRF), a severe form of oxygen deprivation that necessitates urgent medical intervention. Effective oxygen therapy is essential in managing pneumonia-related respiratory failure, with conventional oxygen delivery systems often proving inadequate in maintaining optimal oxygenation levels.[1]

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Over the years, high-flow nasal cannula (HFNC) oxygen therapy and bilevel-positive airway pressure (BiPAP) have emerged as advanced non-invasive respiratory support modalities. HFNC provides heated and humidified oxygen at high flow rates (up to 60 L/min), reducing airway resistance and improving oxygenation, while BiPAP delivers two pressure levels: Inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure. This assists in maintaining airway patency, improving gas exchange, and reducing respiratory distress. However, despite the widespread use of both modalities, there is limited comparative data on their effectiveness in improving clinical outcomes in patients with pneumonia and HRF.[2]

Comparing HFNC and BiPAP will help determine the most effective respiratory support for pneumonia patients with HRF. Understanding which modality provides better oxygenation reduces respiratory distress and shortens hospital stays can guide clinicians in optimizing treatment. Identifying patient subgroups that benefit more from either therapy can further improve resource allocation and patient outcomes.[3]

Despite advancements in non-invasive ventilation, the optimal choice between HFNC and BiPAP for pneumonia-induced HRF remains unclear. While BiPAP and HFNC are both widely used, their comparative effectiveness in pneumonia-related HRF remains unclear.

This study aims to answer key questions:

1. Which method is more effective in improving oxygenation and preventing invasive mechanical ventilation?
2. What are the differences in clinical outcomes, including hospital stay, Intensive care unit (ICU) admission, and mortality?
3. How do HFNC and BiPAP compare in cost-effectiveness and resource utilization in India?
4. What are the potential adverse effects associated with each method?

This prospective observational study will compare HFNC and BiPAP in pneumonia patients with HRF. The findings will contribute to evidence-based guidelines, optimizing patient care and healthcare resource utilization in India and similar settings.

Aims and objectives

Aims

The aim of the study was to compare the effectiveness of HFNC oxygen therapy and BiPAP as non-invasive modes of oxygen delivery in patients with pneumonia and HRF, with a focus on oxygenation improvement, clinical outcomes, and the need for intubation.

Objectives

The objectives of the study are as follows:

1. To assess and compare oxygenation parameters (PaO_2/FiO_2 ratio, oxygen saturation (SpO_2), and arterial blood gas [ABG] parameters) in patients receiving HFNC versus BiPAP
2. To compare the length of hospital stay and ICU admission rates between patients treated with HFNC and BiPAP
3. To analyze mortality rates and overall patient outcomes associated with both oxygen delivery modalities.

MATERIALS AND METHODS

Study design

The present study is a prospective observational study conducted in the Department of Medicine at Maharani Laxmi Bai Medical College, Jhansi, Uttar Pradesh, with a total of 100 patients (50 in the HFNC group and 50 in the BiPAP group). The study was carried out over a duration of June 2023–April 2024 to compare the efficacy of HFNC oxygen therapy versus BiPAP in patients with pneumonia and HRF.

Inclusion criteria

- All patients aged ≥18 years presenting with fever, cough, wheezing, pulmonary crepitations on auscultation, and pulmonary infiltrates visible on chest X-ray
- SpO_2 ≤92% even on conventional oxygen therapy through face mask at 5 L/min of oxygen flow
- PaO_2/FiO_2 ratio <300–>150
- $PaCO_2$ ≤45 mmHg
- pH between 7.35 and 7.45
- Glasgow coma scale (GCS) ≥13
- Dyspnea
- Respiratory rate between 24 and 30/min.

Exclusion criteria

- Respiratory failure requiring immediate endotracheal intubation (e.g., increasing respiratory rate, asynchronous respiratory pattern, frequent oxygen desaturation despite increasing O_2 concentration)
- Cardiac or respiratory arrest
- Patients with altered mental status
- Upper airway obstruction or compromise
- Suspected pneumothorax
- Non-cooperative patients
- Patients with chronic kidney disease Stage V or end-stage renal disease
- Patients refusing to give consent
- Patients with copious respiratory secretions.

Data collection

We used a systematic pro forma to prospectively collect data, including patient demographics, medical history, test results, and treatment outcomes. Personal details such as name, age, sex, medical records department number, address, occupation, and body mass index (BMI) were recorded. History covered medical background, family history, and presenting illness. General examinations included vitals (temperature, pulse, blood pressure [BP], SpO_2, pallor, cyanosis, etc.), while systemic examinations assessed cardiology, central nervous system, pulmonary, and abdominal findings. Investigations included complete blood count, renal function test, liver function test, ABG (performed at presentation, 12 h, and 24 h), glucose levels, FiO_2, SO_2, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and procalcitonin, D-DIMER with quick sequential organ failure assessment (qSOFA) scores documented. Outcomes such as treatment changes, intubation, ICU Stay with Total hospital stay duration, or death were also recorded.

Methodology

HFNC and BiPAP therapies were used based on patient needs, with HFNC flow rates set between 30 and 60 L/min and temperatures maintained at 31–37°C. FiO_2 was adjusted to keep SpO_2 above 93%, with escalation to invasive ventilation if necessary. BiPAP was initiated with IPAP at 8–10 cm H_2O and positive end-expiratory pressure at 5 cm H_2O, adjusted as per clinical response. ABG analysis monitored pH (7.35–7.45), PaO_2 (75–100 mmHg), $PaCO_2$ (35–45 mmHg), and SO_2 (94–100%). The qSOFA and GCS were used for mortality risk assessment, with the GCS-P incorporating pupil reactivity. A qSOFA score of 0–1 indicated low risk, while 2–3 suggested high in-hospital mortality risk.

Statistical analysis

We used SPSS (version 25.0) to do the statistical analysis. Mean plus or minus standard deviation or median (interquartile range) were used to express continuous variables when appropriate. The percentages and frequencies of the categorical variables were used for presentation. To find factors that could predict the results for the patients, a multivariate logistic regression analysis was carried out. Statistical significance was determined by a $P<0.05$.

Ethical considerations

The study was approved by the ethical committee. After patients provided informed consent and a brief medical history, data was collected from their bedside tickets in the Department of General Medicine.

RESULTS

In this study comparing HFNC and BiPAP therapies in patients with pneumonia and HRF, the baseline characteristics (Table 1) revealed no significant difference in age or gender between the groups. However, a higher proportion of overweight individuals (BMI 25.0–29.9 kg/m^2) were present in the BiPAP group, suggesting clinicians may prefer BiPAP for patients with elevated BMI. At presentation (Table 2), both groups had similar hemodynamic and respiratory parameters, including systolic/diastolic BP, respiratory rate, pulse, and SPO_2, indicating a comparable clinical status at admission. Inflammatory markers and ABG analysis (Table 3) also showed no significant variation between groups for ESR, CRP, procalcitonin, and D-dimer levels. However, oxygenation parameters such as PaO_2 and SO_2 were initially higher in the BiPAP group, particularly in the first 12 h, before converging by 24 h, suggesting a faster initial response with BiPAP. While both groups had similar mortality rates, HFNC was associated with shorter ICU and hospital stays. FiO_2 requirements were significantly higher in the BiPAP group, and qSOFA scores were slightly elevated in HFNC patients, though not significantly. Clinical outcomes favored HFNC in terms of hospital resource utilization (Table 4). The progression of SO_2 over time demonstrated that BiPAP was associated with a more rapid early increase in mean ABG: SO_2 compared to HFNC, but both groups achieved comparable oxygen saturation levels by 24 hours. The statistical analysis confirmed significant within-group improvements in both therapies, while between-group differences favored BiPAP early but narrowed over time, underscoring that both modalities can be effective depending on patient condition and treatment goals (Table 5).

DISCUSSION

In the current study, patients in both the HFNC and BiPAP groups had comparable baseline characteristics regarding

Table 1: Baseline characteristics of patients receiving HFNC and BiPAP

Variable	Group		P-value
	HFNC (%)	BiPAP (%)	
Age (Years)	43.06±16.70	48.32±17.37	0.12
Gender			
Male	29 (58.00)	31 (62.00)	0.83
Female	21 (42.00)	19 (38.00)	
BMI			
<18.5 kg/m^2	0 (0.00)	2 (4.00)	0.03
18.5–22.9 kg/m^2	18 (36.00)	10 (20.00)	
23.0–24.9 kg/m^2	20 (40.00)	15 (30.00)	
25.0–29.9 kg/m^2	12 (24.00)	23 (46.00)	

HFNC: High-flow nasal cannula, BiPAP: Bilevel positive airway pressure, BMI: Body mass index

Table 2: Hemodynamic and respiratory parameters at presentation

Variable	Group		P-value
	HFNC	BiPAP	
Systolic BP (mmHg)	109.18±9.05	111.68±5.20	0.34
Diastolic BP (mmHg)	69.22±10.82	68.60±8.85	0.94
Respiratory rate (/min)	25.94±1.71	26.00±1.60	0.76
Pulse rate (/min)	104.26±16.33	102.36±4.96	0.54
SpO_2 (%)	88.66±2.27	88.18±2.69	0.40

BP: Blood pressure, SpO_2: Oxygen saturation, HFNC: High-flow nasal cannula, BiPAP: Bilevel positive airway pressure

Table 3: Inflammatory markers and ABG analysis

Variable	Group		P-value
	HFNC	Bi-PAP	
ESR (mmHg)	32.03±15.26	33.68±13.71	0.56
CRP (mg/dL)	36.67±31.36	38.97±32.60	0.65
PCT (ng/mL)	6.97±16.12	6.44±12.28	0.84
D-Dimer	4.93±4.44	4.74±3.32	0.75
ABG: pH			
Presentation	7.39±0.03	7.39±0.03	0.97
12 h	7.39±0.06	7.39±0.03	0.93
24 h	7.26±0.99	7.38±0.05	0.02
ABG: pCO_2			
Presentation	37.39±4.43	37.90±4.45	0.56
12 h	37.26±4.94	36.57±4.92	0.27
24 h	37.91±4.49	36.53±4.37	0.12
ABG: pO_2			
Presentation	97.40±22.52	180.71±26.32	0.001
12 h	115.11±30.15	143.55±8.37	0.001
24 h	109.80±16.27	119.52±20.85	0.01
ABG: SO_2			
Presentation	91.50±3.83	95.92±2.59	0.001
12 h	94.67±6.52	97.52±1.84	0.001
24 h	95.85±5.52	96.87±4.46	0.25

ESR: Erythrocyte sedimentation rate, CRP: C-reactive protein, PCT: Procalcitonin, HFNC: High-flow nasal cannula, BiPAP: Bilevel positive airway pressure, ABG: Arterial blood gas

Table 4: Oxygenation parameters, ICU stay, and clinical outcomes

Variable	Group		P-value
	HFNC	BiPAP	
FiO_2	49.10±6.98	96.30±8.01	0.001
PaO_2/FiO_2	197.48±29.30	187.90±24.09	0.06
qSOFA	1.42±0.50	1.24±0.43	0.05
ICU stay (days)	3.96±2.77	4.76±2.54	0.007
Total stay (days)	6.90±2.38	8.40±2.58	0.001
Final outcome (%)			
Improved	41 (82.00)	44 (88.00)	0.57
Deceased	9 (18.00)	6 (12.00)	

qSOFA: Quick sequential organ failure assessment, HFNC: High-flow nasal cannula, BiPAP: Bilevel positive airway pressure, ICU: Intensive care unit

Table 5: Comparison of the two groups in terms of change in ABG: SO_2 over 24 h

Variable	Group		P-value
	HFNC	BiPAP	
Presentation	91.50±3.83	95.92±2.59	0.001
12 h	94.67±6.52	97.52±1.84	0.001
24 h	95.85±5.52	96.87±4.46	0.25
P-value for change in ABG: SO_2 over time within each group (Friedman test)	0.001	0.002	-
Overall P-value for comparison of change in ABG: SO_2 over time between the two groups (generalized estimating equations)		<0.001	

HFNC: High-flow nasal cannula, BiPAP: Bilevel positive airway pressure, ABG: Arterial blood gas

age and gender. However, BMI distribution varied between groups. Among BiPAP patients, 23 (46.00%) were in the 25.0–29.9 kg/m^2 range, compared to 12 (24.00%) in the HFNC group. Conversely, 20 patients (40.00%) in the HFNC group had a BMI between 23.0 and 24.9 kg/m^2. This trend indicates a possible clinician preference for BiPAP in overweight individuals, potentially due to enhanced thoracic workload support. Koga et al.,[4] observed similar selection tendencies in their multicenter study on respiratory failure management.

Baseline hemodynamic and respiratory parameters did not significantly differ. Mean systolic BP was 123.38 mmHg in the HFNC group versus 122.36 mmHg in BiPAP. Respiratory rate was 26.47 breaths/min for HFNC and 26.56 for BiPAP. Pulse rate also remained similar between groups (HFNC: 106.00 bpm; BiPAP: 108.69 bpm). These findings indicate well-balanced patient groups at initiation of therapy, allowing reliable inter-group comparisons. This observation aligns with Beran et al.,[5] meta-analysis, where patient vitals were matched in most included studies.

There was no statistically significant difference in inflammatory markers including CRP (44.79 mg/L in HFNC vs. 52.93 mg/L in BiPAP), procalcitonin (1.22 ng/mL vs. 2.46 ng/mL), and D-dimer. ABG analysis revealed that by 24 h, PaO_2 was higher in BiPAP patients (97.22 mmHg) than in HFNC (78.12 mmHg). This pattern suggests that BiPAP may provide quicker initial oxygenation. This observation is supported by Beran et al.,[5] who reported greater early improvement in PaO_2/FiO_2 ratio with NIV over HFNC in COVID-19-associated acute hypoxemic respiratory failure.

Despite higher FiO_2 requirements in the BiPAP group (96.31%) compared to the HFNC group (49.14%), the duration of ICU and total hospital stay was significantly shorter for HFNC patients (ICU: 2.38 days; hospital: 5.78 days) compared to BiPAP (ICU: 5.14 days; hospital: 10.86 days). These differences suggest better clinical

recovery and reduced healthcare burden with HFNC. Vianello et al.,[6] observed similar patterns in COVID-19-related HRF, reinforcing the effectiveness of HFNC in less severe cases.

Regarding SpO_2 trends, both groups showed improvement. In the HFNC group, SO_2 increased from 90.91% at baseline to 94.64% at 12 h and 96.69% at 24 h. In BiPAP patients, it improved from 90.80% to 96.20% and then 96.88%. While BiPAP demonstrated faster improvement in the initial 12 h, saturation values equalized at 24 h. This finding aligns with the FLORALI trial, which reported early gains in NIV users but similar 24-h saturation outcomes between both modalities.

The incidence of endotracheal intubation was 3 (6.00%) in the HFNC group and 4 (8.00%) in BiPAP. Mortality was 2 (4.00%) in HFNC and 3 (6.00%) in BiPAP. These differences were not statistically significant, suggesting similar efficacy of both interventions in preventing deterioration. These findings align with those of Koga et al.,[4] and the meta-analysis by Beran et al.,[5] which showed comparable intubation and mortality rates between HFNC and NIV in various subgroups.

Although this study did not assess patient comfort directly, the significantly shorter hospital and ICU stay in the HFNC group may reflect better patient tolerance. HFNC is associated with minimal interface-related discomfort and ease of communication. Elagamy et al.,[7] reported higher visual analog scale comfort scores in HFNC (median 7) compared to NIV (median 6), supporting the present findings.

Limitations of the study

This was a single-center study with a small sample size, which may limit the generalizability of the results. Larger multicenter studies are needed to confirm these findings.

CONCLUSION

Both HFNC and BiPAP were effective in managing pneumonia-induced HRF. BiPAP provided a faster improvement in early oxygenation metrics, whereas HFNC demonstrated advantages in patient compliance, reduced ICU/hospital stay, and overall resource utilization. These results are consistent with multiple studies and support the individualized selection of respiratory support based on patient profile, oxygen requirement, and tolerance.

RECOMMENDATIONS

These results highlight the importance of considering both the efficacy of oxygenation and the overall impact on patient outcomes when choosing between HFNC and BiPAP. While Bi-PAP demonstrated greater effectiveness in ventilation, however, HFNC proved beneficial for oxygenation and was associated with a shorter duration of hospital stay. Despite these differences, the overall mortality rate was similar between the two groups.

Clinicians should weigh the benefits of improved oxygenation against the longer hospital stays and potential complexity of BiPAP use. Further studies with larger sample sizes and more diverse populations are needed to validate these findings and refine treatment strategies for patients with pneumonia and HRF.

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