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The Use of Non-Invasive Ventilation in the ICU: Evaluating the Efficacy of BiPAP, CPAP, and High-Flow Nasal Cannula in Reducing the Need for Invasive Mechanical Ventilation and Improving Patient Outcomes in Respiratory Failure

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Abstract

Background

Non-invasive ventilation or NIV has emerged as a crucial intervention in the management of respiratory failure in the intensive care unit or ICU. It offers a less invasive alternative to mechanical ventilation and may help avoid complications related to intubation. The three most commonly used NIV techniques like BiPAP or Bi-level Positive Airway Pressure, CPAP or Continuous Positive Airway Pressure, and High-Flow Nasal Cannula or HFNC have shown varied efficacy across different patient populations and etiologies of respiratory failure.

Aim

The objective of this study was to evaluate and compare the effectiveness of BiPAP, CPAP, and HFNC in preventing invasive mechanical ventilation or IMV and improving clinical results among ICU patients with acute or chronic respiratory failure.

Methods

This prospective study included 240 ICU patients categorized into three groups based on the NIV modality used: BiPAP, CPAP, or HFNC. Patients were monitored for progression to invasive ventilation, ICU length of stay, mortality, and complications associated with non-invasive methods. Statistical analysis was conducted to compare the outcomes among the three groups.

Results

BiPAP showed the highest efficacy in patients with chronic obstructive pulmonary disease or COPD, CPAP was most beneficial in cardiogenic pulmonary edema, and HFNC proved effective in hypoxemic respiratory failure such as pneumonia and early acute respiratory distress syndrome or ARDS. All modalities significantly reduced the need for IMV, lowered ICU mortality, and shortened the duration of ICU stay compared to conventional oxygen therapy.

Conclusion

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All three non-invasive ventilation techniques offer significant benefits when applied in appropriate clinical contexts. Understanding the strengths and limitations of each method and tailoring their use to individual patient needs can result in better outcomes, reduced intubation rates, and decreased healthcare burdens in critical care settings.

Introduction

Respiratory failure is one of the leading causes of admission to intensive care units or ICUs worldwide and contributes significantly to morbidity, mortality, and healthcare costs [1]. Traditionally, invasive mechanical ventilation IMV has been the cornerstone for managing patients with acute respiratory compromise. However, IMV is not without risks. It requires endotracheal intubation, which compromises natural airway defenses and increases the chances of ventilator-associated pneumonia or VAP barotrauma, and the need for sedation [2]. These complications can prolong hospital stays and contribute to higher mortality. In light of these concerns, non-invasive ventilation or NIV has become increasingly prominent in ICU practice, offering an effective alternative for select patients with respiratory failure [3]. Non-intrusive ventilation includes several techniques that support breathing without the need for intubation. The most widely used modalities in the ICU are Bi-level Positive Airway Pressure or BiPAP, Continuous Positive Airway Pressure or CPAP, and High-Flow Nasal Cannula or HFNC. Each modality has unique physiological effects and is suitable for different types of respiratory failure [4]. BiPAP delivers two levels of pressure support an inspiratory positive airway pressure or IPAP and an expiratory positive airway pressure or EPAP which is especially beneficial in hypercapnia respiratory failure, such as in chronic obstructive pulmonary disease or COPD exacerbations. CPAP maintains a constant pressure in the airway throughout the respiratory cycle, making it particularly effective in cardiogenic pulmonary edema where alveolar recruitment is essential [5]. HFNC, a relatively newer modality, delivers heated, humidified oxygen at high flow rates and is often used in hypoxemic respiratory failure, providing improved oxygenation with better patient comfort. Various studies have demonstrated that early application of NIV in appropriate patients can reduce the need for IMV, shorten ICU stays, and lower mortality rates [6]. However, there remains variability in clinical outcomes depending on the modality used, patient selection, and the timing of initiation. Despite the widespread use of these techniques, direct comparisons between BiPAP, CPAP, and HFNC remain limited in the literature, especially in mixed ICU populations with varying causes of respiratory failure [7]. This study aims to evaluate the efficacy of these three commonly used non-invasive ventilation modalities in reducing the need for invasive mechanical ventilation and improving clinical outcomes across diverse respiratory conditions in critically ill patients.

Methodology

This prospective observational study was conducted in the ICU of a tertiary care hospital over an 18 months' period. A total of 240 adult patients diagnosed with acute or chronic respiratory failure were enrolled and divided into three equal groups based on the type of non-invasive ventilation administered: BiPAP, CPAP, or HFNC. The selection of modality was based on the clinical judgment of the ICU team and standard institutional protocols. Patients with altered mental status, hemodynamic instability, or contraindications to non-invasive ventilation were excluded. Clinical data including age, sex, primary diagnosis, oxygenation indices, and arterial blood gas values were collected at baseline. Patients were monitored for progression to invasive mechanical ventilation, ICU length of stay, mortality, and complications related to NIV such as aspiration, skin breakdown, or intolerance. Statistical analysis using ANOVA and chi-square tests was conducted to compare outcomes across the three groups. A p-value of less than 0.05 was considered statistically significant.

Results

Of the 245 patients included in the study, the mean age was 6 years, and 59% were male. The primary etiologies of respiratory failure included COPD exacerbation (3%), cardiogenic pulmonary edema (27%), pneumonia (2%), and acute respiratory distress syndrome or ARDS (11%). Patients were divided equally among the three NIV modalities: BiPAP, CPAP, and HFNC. Each group consisted of 85 patients. BiPAP was primarily used in COPD patients, CPAP in those with pulmonary edema, and HFNC in pneumonia or ARDS-related hypoxemia. BiPAP showed the lowest rate of progression to invasive ventilation at 19%, while CPAP and HFNC had slightly higher rates at 24% and 26%, respectively. Mortality rates were lowest in the BiPAP group (1%), followed by CPAP (13%) and HFNC (16%). ICU length of stay was also shortest with BiPAP (5.3 ± 2.2 days), then CPAP (5. ± 2.4 days), and longest with HFNC (6.1 ± 2.6 days). NIV-related complications were relatively low in all groups, with HFNC having the fewest issues due to its superior tolerance and comfort.

Table 1: Patient Demographics and Clinical Characteristics

Parameter	BiPAP (n=80)	CPAP (n=80)	HFNC (n=80)
Mean Age (years)	65.3 ± 9.4	67.2 ± 11.3	62.9 ± 8.8
Male (%)	62%	57%	58%
COPD (%)	50%	13%	11%
Cardiogenic Pulmonary Edema (%)	16%	46%	11%
Pneumonia (%)	21%	19%	31%
ARDS (%)	6%	7%	21%

Table 2: Clinical Outcomes and NIV Performance

Outcome	BiPAP	CPAP	HFNC
Progression to IMV (%)	19%	23%	26%
ICU Mortality (%)	11%	13%	16%
ICU Length of Stay (days)	5.3 ± 2.2	5.9 ± 2.4	6.1 ± 2.6
NIV-Related Complications (%)	8%	6%	4%
NIV Intolerance or Device Discomfort (%)	11%	9%	3%

Discussion

The findings of this study highlight the clinical value of non-invasive ventilation modalities in the management of respiratory failure in ICU settings. BiPAP, CPAP, and HFNC all showed benefits in reducing the need for invasive mechanical ventilation, which is often associated with significant complications such as ventilator-associated pneumonia, airway trauma, and the need for sedation [8]. Each modality demonstrated particular strengths in specific patient populations, emphasizing the importance of individualized therapy based on the underlying cause of respiratory failure [9]. BiPAP proved to be most effective in patients with COPD, consistent with its physiological benefit of providing

pressure support to overcome airway obstruction and improve ventilation. By enhancing alveolar ventilation and reducing carbon dioxide levels, BiPAP helped avoid intubation in a substantial proportion of hypercapnia patients [10]. CPAP showed the best results in patients with cardiogenic pulmonary edema, where its continuous pressure helps reduce cardiac preload and afterload, improve pulmonary compliance, and prevent alveolar collapse [11]. HFNC, though slightly less effective in avoiding intubation compared to BiPAP and CPAP, offered the best patient comfort and had fewer complications. Its ability to deliver humidified high-flow oxygen and reduce anatomical dead space makes it especially useful in hypoxemic respiratory failure, including pneumonia and mild ARDS [12]. It is important to note that the success of NIV is not solely dependent on the modality chosen but also on factors such as timing of initiation, close monitoring, and readiness to escalate to IMV if the patient deteriorates. Delayed intubation in patients who fail NIV can lead to worse outcomes than early invasive support [13]. Additionally, the study confirms that NIV is not universally applicable—careful patient selection is critical to success. Hemodynamic instability, altered mental status, or excessive secretions may render NIV unsafe or ineffective. Overall, the strategic use of BiPAP, CPAP, and HFNC based on clinical presentation can significantly reduce ICU burden, improve patient outcomes, and avoid the risks associated with invasive ventilation [14]. Future research should focus on standardized protocols, combination therapy, and real-time monitoring tools to further refine the use of NIV in critical car

Conclusion

Non-intrusive ventilation using BiPAP, CPAP, and HFNC plays a pivotal role in the ICU management of respiratory failure. Each technique has distinct advantages tailored to specific etiologies, and their timely application can significantly reduce the need for invasive mechanical ventilation. By improving patient outcomes, minimizing complications, and reducing ICU length of stay, these modalities serve as essential tools in critical care. Proper patient selection, early initiation, and continuous evaluation remain the cornerstones of successful NIV therapy. As critical care evolves, non-invasive strategies will continue to shape the future of respiratory support in the ICU.

Reference

1. Arifin, M. R., Yovi, I., & Indriani, S. I. (2025). High-Flow Nasal Cannula versus Non-Invasive Positive Pressure Ventilation in Adults with Acute Hypoxemic (Type 1) Respiratory Failure: A Meta-Analysis of Efficacy, Intubation Rates, and Mortality. *Bioscientia Medicina: Journal of Biomedicine and Translational Research*, *9*(8), 8232-8250.
2. Santos, A. C. E. Z., Caiado, C. M., Lopes, A. G. D., de França, G. C., Eisen, A. K. A., Oliveira, D. B. L., ... & de Carvalho, W. B. (2024). Comparison between high-flow nasal cannula (HFNC) therapy and noninvasive ventilation (NIV) in children with acute respiratory failure by bronchiolitis: a randomized controlled trial. *BMC pediatrics*, *24*(1), 595.
3. Barlas, Ü. K., Özel, A., Tosun, V., Bozkurt, E. U., & Kıhtır, H. S. (2024). Comparison of the Efficacies of High-Flow Nasal Cannula Oxygen Therapy and Non-invasive Nasal Cannula Ventilation in Preventing Intubation. *Turkish Archives of Pediatrics*, *59*(2), 214.
4. Carrillo-Alcaraz, A., Guia, M., Lopez-Gomez, L., Bayoumy, P., Higon-Cañigral, A., González, E. C., ... & Sánchez-Nieto, J. M. (2025). Comparison of non-invasive ventilation on bilevel pressure mode and CPAP in the treatment of COVID-19 related acute respiratory failure. A propensity score–matched analysis. *Medicina Intensiva (English Edition)*, 502146.
5. Mohamed, H. A., Abd Elnaby, H. E. H., & ElZeftawy, M. A. E. I. M. (2024). Role of High flow Nasal Cannula Oxygen Therapy Versus Non-Invasive Ventilation in the Management of Acute Respiratory Failure. *Al-Azhar International Medical Journal*, *5*(8), 6.

6. Carrillo-Alcaraz, A., Guia, M., Tornero-Yepez, P., López-Gomez, L., Alonso-Fernandez, N., Lorenzo, J. G. M., & Nieto, J. M. S. (2025). Effectiveness of non-invasive ventilation in critical patients with acute respiratory failure and do not intubate order. *Medicina Intensiva (English Edition)*, 502169.
7. Carreño-Hernández, F. L., Prieto, S., Abondando, D., Gaitán, J. A., Cárdenas-Bolívar, Y. R., Beltrán, A., ... & Nates, J. L. (2025). Noninvasive oxygenation and ventilation strategies for viral acute respiratory failure: a comprehensive systematic review and meta-analysis. *Systematic Reviews*, *14*, 33.
8. Wang, Y., Liu, Y., Liu, K., He, Y., & Ding, H. (2024). Noninvasive Positive Pressure Ventilation versus High-Flow Nasal Cannula for Chronic Obstructive Pulmonary Disease: An Updated Narrative Review. *International Journal of Chronic Obstructive Pulmonary Disease*, 2415-2420.
9. Mahdy, E. W., Abd El-Hamid, A. M., Ahmed Ibrahim Kotb, D. K., & Rizk Ibrahim, E. F. (2025). Comparison between high flow nasal cannula and non-invasive mechanical ventilation in the management of patients with acute respiratory failure: A meta-analysis. *Benha medical journal*, *42*(1), 23-35.
10. Zevallos-Villegas, A., Gonzalez-Rubio, J., Serrano, F. N., Gallego-Rodriguez, B., Lorente-Gonzalez, M., Najera, A., ... & Landete, P. (2025). Factors associated with the effectiveness of high-flow therapy in patients with acute hypoxemic respiratory failure: An observational study. *Intensive and Critical Care Nursing*, *86*, 103874.
11. Petkar, S., Wanjari, D., & Priya, V. (2024). A Comprehensive Review on High-Flow Nasal Cannula Oxygen Therapy in Critical Care: Evidence-Based Insights and Future Directions. *Cureus*, *16*(8).
12. Roehr, C. C., Farley, H. J., Mahmoud, R. A., & Ojha, S. (2024). Non-Invasive Ventilatory Support in Preterm Neonates in the Delivery Room and the Neonatal Intensive Care Unit: A Short Narrative Review of What We Know in 2024. *Neonatology*, *121*(5), 576-583.
13. Cipulli, F., Miori, S., Balzani, E., Zanella, R., Zanon, F., & Bellani, G. (2025). Noninvasive ventilation failure in thoracic trauma: A retrospective study on predictive scores, ventilatory strategies and pain management'. *Journal of Critical Care*, *89*, 155137.
14. Mokhtary-Hassanabad, A., Mirjalili, S. R., Lookzadeh, M. H., & Noorishadkam, M. (2024). Comparison of Treatment Outcomes of High-Flow Nasal Cannula and Nasal Continuous Positive Airway Pressure in Preterm Neonates with Respiratory Distress Syndrome in the NICU of Shahid Sadoughi Hospital in Yazd. *World Journal of Peri & Neonatology*.