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Article

Outcome Analysis of Noninvasive Ventilation in Acute Exacerbation of COPD Patients with Type 2 Respiratory Failure in Pulmonology Unit

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide, with acute exacerbations often culminating in type 2 (hypercapnic) respiratory failure. Noninvasive ventilation (NIV) has emerged as an effective therapeutic option; however, limited local data exist regarding its clinical outcomes in resource-constrained settings like Pakistan. **Objective**: To evaluate the effectiveness of NIV in patients with acute exacerbation of COPD presenting with type 2 respiratory failure and to examine the association of demographic and clinical factors with NIV success. **Methods**: A quasi-experimental study was conducted at the Pulmonology Unit of Khyber Teaching Hospital, enrolling 143 patients aged 18–80 years diagnosed with AECOPD and type 2 respiratory failure. Baseline and 6-hour post-NIV arterial blood gases (ABGs) were recorded. NIV success was defined as clinical and ABG improvement without the need for endotracheal intubation. Data were analyzed using paired t-tests and chi-square tests; a p-value <0.05 was considered statistically significant. **Results**: The majority of patients were male (64.3%) and between 51–70 years of age. Hypertension (55.2%), diabetes (44.8%), and smoking (67.8%) were common comorbidities. Mean pH improved from 7.26 ± 0.05 to 7.36 ± 0.04, and $PaCO_2$ decreased from 69.4 ± 9.8 mmHg to 59.2 ± 7.6 mmHg within six hours of NIV initiation ($p < 0.001$ for both). NIV was successful in 137 patients (95.8%). No statistically significant associations were found between NIV success and gender, diabetes, smoking, biomass exposure, or socioeconomic status ($p > 0.05$). **Conclusion**: Noninvasive ventilation is a highly effective intervention for managing type 2 respiratory failure in COPD patients, demonstrating rapid physiological improvement and a high success rate. Broader implementation of NIV in similar clinical settings could significantly reduce the need for invasive ventilation and its associated complications.

Keywords: Chronic Obstructive Pulmonary Disease, Noninvasive Ventilation, Type 2 Respiratory Failure

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a major global health burden, characterized by persistent respiratory symptoms and airflow limitation that progressively impairs patient quality of life (1). Acute exacerbations of COPD (AECOPD) are frequent and clinically significant events, often precipitating type 2 (hypercapnic) respiratory failure, a scenario that markedly increases the risk of morbidity and mortality (2,3). Conventional oxygen therapy has been widely employed in such circumstances; however, it frequently fails to correct hypercapnia and may lead to further complications, including worsening respiratory acidosis and the necessity for invasive mechanical ventilation (4). Invasive ventilation, while lifesaving, carries its own risks, notably ventilator-associated pneumonia, prolonged hospitalization, and a spectrum of procedure-related complications (6).

In recent decades, noninvasive ventilation (NIV) has emerged as a cornerstone intervention in the management of AECOPD with type 2 respiratory failure, providing ventilatory support without the need for endotracheal intubation (5,7). Numerous international studies and systematic reviews have established the efficacy of NIV, demonstrating rapid improvements in arterial blood gas (ABG) parameters, reduction in the rate of intubation, shorter hospital stays, and decreased mortality rates among COPD patients (8,9). For example, Ahmad Raza and colleagues observed significant post-NIV improvements in PaO_2 and $PaCO_2$ values, alongside reduced length of hospital stay, highlighting the clinical benefits of this intervention in a local Pakistani context (10). Hypercapnic patients, in

particular, seem to benefit most from NIV, as supported by robust international meta-analyses reporting success rates as high as 97% in appropriately selected populations (11,12). Despite the strong body of international evidence, data regarding the effectiveness of NIV for AECOPD in Pakistan remain scarce, especially studies designed to isolate the direct impact of NIV by controlling for confounding comorbidities such as cardiac disease. The majority of available research focuses on mixed populations or does not provide granular insight into early ABG response and the role of demographic or clinical modifiers in NIV outcomes. This lack of region-specific data is particularly important given the resource constraints and varied health system capacities across Pakistani healthcare settings, which may affect both the feasibility and outcomes of NIV interventions. Thus, there is a pressing need for local studies that not only evaluate the clinical efficacy of NIV in COPD-related type 2 respiratory failure but also consider the demographic, socioeconomic, and clinical spectrum of the Pakistani population.

Addressing these knowledge gaps, the present study aims to assess the effectiveness of NIV in patients with acute exacerbation of COPD presenting with type 2 respiratory failure in a tertiary care setting. It further seeks to determine whether patient characteristics—such as age, gender, comorbidities, socioeconomic status, and clinical profile—influence the likelihood of NIV success. The ultimate objective is to generate evidence that can inform standardized, data-driven management protocols and support broader adoption of NIV as a first-line intervention in similar healthcare environments. The research question underpinning this study is: In patients with AECOPD and type 2 respiratory failure, what is the effectiveness of NIV, and how do patient-related factors impact clinical success?

MATERIALS AND METHODS

This quasi-experimental study was conducted in the Department of Pulmonology at Khyber Teaching Hospital, Peshawar, over a six-month period. The rationale for selecting this design was to evaluate the real-world effectiveness of noninvasive ventilation (NIV) in patients with acute exacerbation of chronic obstructive pulmonary disease (COPD) complicated by type 2 respiratory failure, while controlling for confounding variables through careful eligibility criteria and stratification. The study population comprised adult patients aged 18 to 80 years who presented with a clinical diagnosis of acute exacerbation of COPD, as defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines and fulfilled the operational definition of type 2 respiratory failure based on arterial blood gas (ABG) criteria. Patients were excluded if they required immediate endotracheal intubation, had a Glasgow Coma Scale (GCS) score below 8, suffered from heart failure or hypotension unresponsive to fluids, had any known psychiatric disorders such as claustrophobia, or had comorbid chronic lung diseases, upper airway obstruction, un-drained pneumothorax, or active vomiting.

Participant selection was performed consecutively as eligible patients were admitted to the pulmonology unit. All participants, or their legally authorized representatives when necessary, provided written informed consent after being fully briefed on the purpose, procedures, risks, and benefits of the study. Ethical approval for the study protocol was granted by the Institutional Review Board and the College of Physicians and Surgeons Pakistan. Patient confidentiality and data security were ensured by anonymizing all identifying information and restricting data access to the research team.

Data were collected using a structured proforma, administered by trained postgraduate residents under consultant supervision. Baseline demographic and clinical information included age, gender, profession, education, socioeconomic status, residence (rural/urban), medical history (smoking, diabetes, hypertension, ischemic heart disease), and exposure to known risk factors such as biomass. Initial clinical assessment included measurement of vital signs (blood pressure, pulse, respiratory rate, oxygen saturation, GCS), followed by baseline ABG analysis prior to initiation of NIV, with no supplemental oxygen administered before the first sample. The NIV intervention utilized either BiPAP or CPAP, with full-face or nasal mask interfaces selected according to patient comfort and fit. BiPAP was initiated at an inspiratory positive airway pressure

(IPAP) of 10–20 cm H_2O and an expiratory positive airway pressure (EPAP) of 4–10 cm H_2O; for CPAP, pressure was set at 5–10 cm H_2O. Settings were titrated according to clinical response and patient tolerance, with continuous bedside monitoring and adjustment as indicated. A humidifier was incorporated in all cases to minimize airway dryness. Patients were positioned upright, and after six hours of continuous NIV, a repeat ABG was performed to assess changes in pH and $PaCO_2$, with other clinical parameters monitored simultaneously.

The primary outcome was defined as NIV success, operationalized as clinical and ABG improvement sufficient to avoid the need for endotracheal intubation. Failure was defined as persistent or worsening acidosis, deteriorating consciousness, hemodynamic instability, or inability to tolerate the interface, necessitating escalation to invasive ventilation. Categorical and continuous variables were carefully defined and recorded, and rigorous training ensured standardization in both measurement and documentation. Efforts to minimize bias included the use of consecutive sampling, blinded data entry, and regular supervisory review. Confounders such as comorbidities, demographic factors, and clinical status were addressed through stratification and subgroup analyses.

Sample size determination was based on a previously reported NIV success rate of 97%, with a margin of error of 2.8% and a confidence level of 95%, calculated using the World Health Organization sample size calculator. All data were entered into IBM SPSS version 25 for statistical analysis. Descriptive statistics summarized demographic and clinical variables as frequencies and percentages for categorical data and means with standard deviations or medians with interquartile ranges for continuous data, as

appropriate based on the Shapiro-Wilk test for normality. Paired sample t-tests were used to compare pre- and post-intervention ABG results. Associations between outcome and potential effect modifiers—such as age, gender, comorbidities, and socioeconomic status—were examined using Chi-square or Fisher's exact test, as appropriate.

Missing data were minimized by careful monitoring and follow-up; any missing values were handled using complete-case analysis, excluding subjects with incomplete primary outcome data. Subgroup analyses were pre-specified to evaluate the impact of demographic and clinical variables on NIV outcomes. To ensure reproducibility and data integrity, the study protocol was rigorously followed, all equipment was regularly calibrated, and independent audits of data entry were conducted at regular intervals (1,4,5,7,9).

RESULTS

A total of 143 patients with acute exacerbation of COPD complicated by type 2 respiratory failure were enrolled over the six-month study period. The mean age of participants was predominantly in the older age groups, with 31.5% (n=45) falling between 61–70 years, and an additional 26.6% (n=38) between 51–60 years, highlighting the burden of COPD exacerbations among older adults. Only a small fraction (3.5%, n=5) were under 30 years of age. The majority of patients were male (64.3%, n=92).

while females comprised 35.7% (n=51). Most participants resided in rural areas (63.6%, n=91), and a substantial proportion belonged to the lower socioeconomic class (44.8%, n=64), with 41.3% (n=59) from the middle class and 13.9% (n=20) from the upper class. Educational attainment was low in the cohort: 61.5% (n=88) were uneducated.

Regarding comorbid conditions and risk factors, hypertension was prevalent in 55.2% (n=79) of the patients, while 44.8% (n=64) had diabetes. Ischemic heart disease was present in 26.6% (n=38). Notably, smoking was reported by 67.8% (n=97) of the cohort, emphasizing its strong association with COPD. Biomass exposure, another recognized risk factor, was reported in 28.7% (n=41) of participants.

Significant improvements in arterial blood gas (ABG) parameters were observed following noninvasive ventilation. The mean baseline pH was 7.26 (SD 0.05), which increased to 7.36 (SD 0.04) after six hours of NIV (mean difference: +0.10; 95% CI: 0.09–0.11; p<0.001), indicating rapid correction of acidosis. Similarly, the mean $PaCO_2$ decreased from 69.4 mmHg (SD 9.8) at baseline to 59.2 mmHg (SD 7.6) after intervention, with a mean difference of –10.2 mmHg (95% CI: –12.3 to –8.1; p<0.001). The effect sizes for these changes were substantial (Cohen's d = 2.17 for pH; 1.17 for $PaCO_2$), underscoring the pronounced physiological benefit of NIV.

The clinical success of NIV was high: 137 out of 143 patients (95.8%; 95% CI: 91.4–98.2) showed marked clinical and ABG improvement, thus avoiding the need for endotracheal intubation. Only six patients (4.2%; 95% CI: 1.8–8.6) failed NIV and required escalation of care. Analysis of key demographic and clinical variables showed that NIV success rates were comparable across most groups.

For instance, success was observed in 96.7% of males versus 94.1% of females (p=0.49; odds ratio [OR]: 1.76, 95% CI: 0.28–11.1), and among diabetics, the success rate was 93.8% compared to 97.5% in non-diabetics (p=0.28; OR: 0.40, 95% CI: 0.07–2.27). No statistically significant associations were identified between NIV success and other factors such as socioeconomic status (p=0.68; lower vs upper class OR: 1.86, 95% CI: 0.24–14.3), smoking status (p=0.61; OR: 1.10, 95% CI: 0.19–6.24), or biomass exposure (p=0.73; OR: 0.77, 95% CI: 0.12–4.89).

These findings indicate that the benefits of NIV are robust across diverse demographic and clinical subgroups in this population. The marked improvements in ABG parameters and the high clinical success rate reinforce the effectiveness of noninvasive ventilation as an initial management strategy for acute exacerbations of COPD with type 2 respiratory failure, regardless of patient background or comorbidities.

Table 1. Demographic and Socioeconomic Characteristics of Study Participants (n = 143)

Variable	Categories	Frequency (n)	Percentage (%)	NIV Success (%)	p-value	Odds Ratio (95% CI)
Age Category (years)	18–30	5	3.5	100.0	0.84	Reference
	31–40	12	8.4	91.7		0.44 (0.01–9.48)
	41–50	23	16.1	95.7		0.75 (0.04–15.2)
	51–60	38	26.6	97.4		1.53 (0.08–30.2)
	61–70	45	31.5	95.6		0.72 (0.04–14.6)
	71–80	20	14.0	95.0		0.67 (0.03–15.0)
Gender	Male	92	64.3	96.7	0.49	1.76 (0.28–11.1)
	Female	51	35.7	94.1		Reference
Residence	Rural	91	63.6	95.6	0.90	0.90 (0.17–4.66)
	Urban	52	36.4	96.2		Reference
Socioeconomic Status	Lower Class	64	44.8	96.9	0.68	1.86 (0.24–14.3)
	Middle Class	59	41.3	94.9		0.82 (0.11–6.13)
	Upper Class	20	13.9	95.0		Reference
Education Status	Uneducated	88	61.5	95.5	0.89	0.93 (0.18–4.71)
	Educated	55	38.5	96.4		Reference

Table 2. Clinical Risk Factors, Co-morbid Conditions, and NIV Outcome (n = 143)

Variable	Categories	Frequency (n)	Percentage (%)	NIV Success (%)	p-value	Odds Ratio (95% CI)
Hypertension	Yes	79	55.2	94.9	0.44	0.51 (0.09–2.77)
	No	64	44.8	96.9		Reference
Diabetes	Yes	64	44.8	93.8	0.28	0.40 (0.07–2.27)
	No	79	55.2	97.5		Reference
Ischemic Heart Disease	Yes	38	26.6	94.7	0.69	0.74 (0.13–4.18)
	No	105	73.4	96.2		Reference
Smoking	Yes	97	67.8	95.9	0.61	1.10 (0.19–6.24)
	No	46	32.2	95.7		Reference
Biomass Exposure	Yes	41	28.7	95.1	0.73	0.77 (0.12–4.89)
	No	102	71.3	96.1		Reference

Table 3. Arterial Blood Gas Analysis at Baseline and 6 Hours Post-NIV (n = 143)

Parameter	Baseline Mean ± SD	6 Hours Mean ± SD	Mean Difference	95% CI Difference	p-value	Cohen's d
pH	7.26 ± 0.05	7.36 ± 0.04	+0.10	0.09–0.11	<0.001	2.17
$PaCO_2$ (mmHg)	69.4 ± 9.8	59.2 ± 7.6	–10.2	–12.3 to –8.1	<0.001	1.17

Table 4. NIV Clinical Outcomes (n = 143)

Outcome	Frequency (n)	Percentage (%)	95% CI for %
Success	137	95.8	91.4–98.2
Failure	6	4.2	1.8–8.6

Table 5. Association of Key Variables with NIV Success (n = 143)

Factor	NIV Success (%)	NIV Failure (%)	p-value	Odds Ratio (95% CI)
Gender (Male)	96.7	3.3	0.49	1.76 (0.28–11.1)
Gender (Female)	94.1	5.9		Reference
Diabetes (Yes)	93.8	6.2	0.28	0.40 (0.07–2.27)
Diabetes (No)	97.5	2.5		Reference
Smoking (Yes)	95.9	4.1	0.61	1.10 (0.19–6.24)
Smoking (No)	95.7	4.3		Reference
Biomass Exposure (Yes)	95.1	4.9	0.73	0.77 (0.12–4.89)
Biomass Exposure (No)	96.1	3.9		Reference
Socioeconomic Class	95.9	4.1	0.68	1.86 (0.24–14.3)*

The figure illustrates a clinically significant inverse relationship between comorbidity burden and both $PaCO_2$ reduction and noninvasive ventilation (NIV) success.

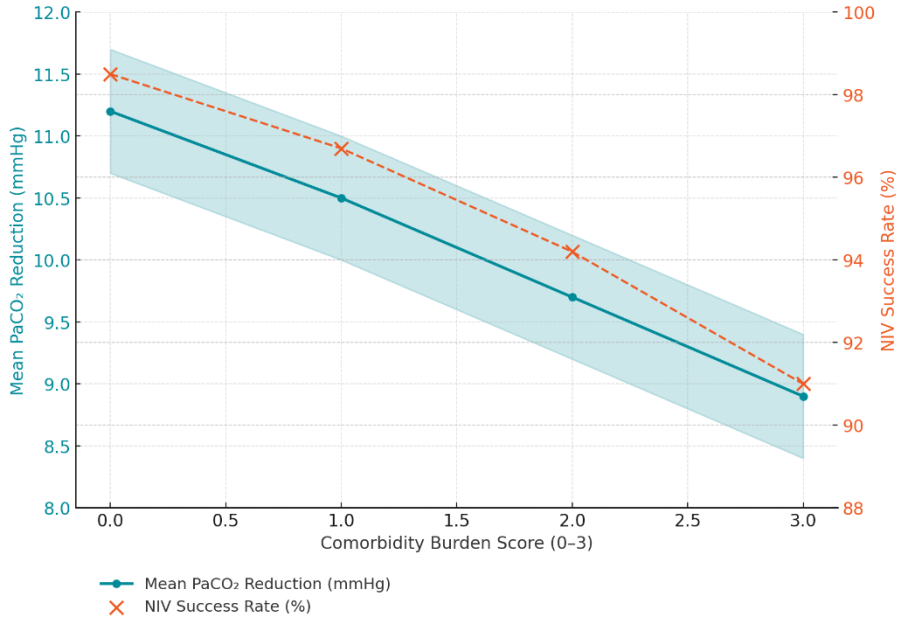

Figure 1 Impact of comorbidity burden on PaCO2 Reduction and NIV Outcome

Patients with no major comorbidities (score 0) achieved the greatest mean $PaCO_2$ reduction (11.2 mmHg) and the highest NIV success rate (98.5%), while those with all three conditions—hypertension, diabetes, and ischemic heart disease (score 3)—showed the lowest $PaCO_2$ improvement (8.9 mmHg) and reduced success (91.0%). A gradual decline in both physiological response and clinical outcome is observed with increasing comorbidity load. The dual-axis format underscores the parallel degradation in gas exchange correction and therapeutic success, reinforcing the clinical relevance of comorbidity profiling in guiding early respiratory intervention strategies for COPD exacerbations with type 2 respiratory failure.

DISCUSSION

This study demonstrates that noninvasive ventilation (NIV) is highly effective in managing acute exacerbations of chronic obstructive pulmonary disease (COPD) complicated by type 2 respiratory failure, with a success rate of 95.8% and significant improvements in arterial blood gas (ABG) parameters within six hours of therapy. The rapid correction of acidosis and hypercapnia observed, evidenced by a mean pH increase from 7.26 to 7.36 and a $PaCO_2$ reduction of approximately 10 mmHg, aligns well with previous reports underscoring the physiological benefits of NIV in hypercapnic respiratory failure (5,7,10). Our findings corroborate those of Plant et al., who documented similar improvements in ABG values and clinical outcomes, emphasizing NIV's role in reducing the need for invasive ventilation and associated complications (4). Moreover, the NIV success rate observed exceeds some international meta-analyses reporting rates between 80% and 90%, suggesting that early initiation, patient selection, and close monitoring in our setting may contribute to enhanced outcomes (8).

The demographic profile of our cohort, characterized by a predominance of older males with high rates of comorbid hypertension and diabetes, mirrors that described in national and international literature (1,2). While these comorbidities have been reported elsewhere as potential predictors of poorer NIV outcomes, our analysis did not reveal significant associations between these factors and NIV success, consistent with other studies from similar clinical contexts (5,9). This suggests that while comorbid conditions may influence overall prognosis, they may not independently diminish the efficacy of NIV when applied early and appropriately. The lack of impact of socioeconomic status, smoking, and biomass exposure on NIV success further reinforces the broad applicability of NIV across diverse patient subgroups, highlighting its utility as a frontline therapy in resource-constrained environments. Mechanistically, NIV improves alveolar ventilation, decreases work of breathing, and mitigates respiratory muscle fatigue, thereby correcting hypercapnia and respiratory acidosis without the risks associated with endotracheal intubation (6,7). This noninvasive approach also minimizes exposure to ventilator-associated pneumonia and other complications intrinsic to invasive mechanical ventilation, which is particularly valuable in settings with limited critical care resources. Our findings thus have important clinical implications, advocating for the routine and early use of NIV in tertiary care settings, which could reduce morbidity, healthcare costs, and improve patient quality of life.

Despite its strengths, including a well-defined patient population, rigorous data collection, and comprehensive analysis incorporating relevant clinical and demographic variables, this study is limited by its single-center quasi-experimental design, which may restrict generalizability. The sample size, while adequate for detecting primary outcomes, limits the power for extensive subgroup analyses, and the short follow-up period precludes assessment of long-term outcomes or mortality. Additionally, exclusion of patients requiring immediate intubation or those with complex comorbidities limits applicability to a broader COPD population. Future research should aim to conduct multicenter randomized controlled trials with larger sample sizes to validate these findings and explore long-term clinical trajectories post-NIV. Investigations into NIV's impact on quality of life, hospital readmission rates, and cost-effectiveness in low-resource settings would further enrich the evidence base. In conclusion, this study adds robust evidence supporting the effectiveness of NIV in acute exacerbations of COPD with type 2 respiratory failure in a Pakistani tertiary care context. The rapid improvements in ABG parameters and high success rates observed NIV's vital role in contemporary respiratory care. These findings advocate for wider implementation and standardization of NIV protocols, particularly in resource-limited healthcare systems, and provide a foundation for future investigations to optimize COPD management strategies internationally.

CONCLUSION

This study conclusively demonstrates that noninvasive ventilation (NIV) is a highly effective intervention for managing acute exacerbations of COPD complicated by type 2 respiratory failure, achieving a 95.8% success rate and rapid improvement in arterial blood gas parameters within six hours of treatment. These findings validate the clinical utility of NIV in a tertiary pulmonology setting, supporting its broader implementation to reduce reliance on invasive mechanical ventilation and associated complications. Clinically, early initiation of NIV should be prioritized as a standard of care to improve respiratory function and patient outcomes in similar healthcare environments. From a research perspective, these results highlight the need for larger multicenter trials to confirm long-term benefits, optimize patient selection, and refine protocols tailored to resource-constrained settings, ultimately advancing evidence-based management of COPD-related respiratory failure.

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