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Research Article

The ventilatory effect of High Velocity Nasal Insufflation versus Non-invasive Positive Pressure Ventilation in the treatment of acute hypercapnic respiratory failure in patients with AECOPD

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Abstract

Background: High-Velocity Nasal Insufflation (Hi-VNI) is a type of non-invasive ventilation (NIV) that doesn't require a face mask and is used to help oxygenate patients experiencing respiratory distress. At flow rates of 35 liters per minute, it can completely clear extrathoracic dead space, besides oxygenation support. It may also be able to provide ventilatory assistance in patients suffering from acute type II respiratory failure. This study evaluated the ventilatory support capabilities of Hi-VNI, a type of high flow nasal cannula (HFNC), and Non-invasive Positive Pressure Ventilation (NIPPV) for Acute Exacerbation of Chronic Obstructive Pulmonary Disease (AECOPD) patients with type II respiratory failure. **Patients and methods:** Seventy-four AECOPD patients presented to Cardiothoracic Minia University Hospital during the period from November 2022 to January 2024 by acute hypercapnic respiratory failure were enrolled in this study. Cases were divided into two categories based on the first line of ventilatory support used, including NIPPV group (40 patients) and Hi-VNI group (34 patients). Patients were subjected to detailed medical history, clinical evaluation, full laboratory tests, plain Chest radiographs, computed tomography if indicated and analysis of arterial blood gases (ABGs) at baseline, after 1 hour, 2hrs, 6hrs, 24hrs and on discharge. **Results:** 34 of the 74 included patients were randomized to Hi-VNI and 40 patients to NIPPV and both groups were compared regarding the ventilatory effect of the used regimen. The therapeutic impact on Respiratory Rate (RR), hydrogen ion concentration (pH), partial pressure of carbon dioxide in arterial blood ($PaCO_2$) and partial pressure of arterial oxygen (PaO_2) over time in every group were similar. The intubation rate was17.6% in the Hi-VNI group and 25% in the NIPPV group (p value = 0.244). The percentage of patients who do not improve after treatment was *35.3%* in the Hi-VNI group and *32.5%* in the NIPPV group (p value = 1.0). **Conclusion:** Hi-VNI may provide ventilatory support similar to NIPPV in COPD patients presenting with acute type II respiratory failure. More research is required to confirm these results.

Keywords: AECOPD, Hi-VNI, HFNC, NIPPV and acute type II respiratory failure.

Introduction

Acute Exacerbation COPD is an episode marked by increased dyspnea, coughing and expectoration that worsens in less than two weeks. It may also be accompanied by increased heart rate and/or RR and is frequently associated with increased local and systemic inflammation brought by infection, pollution, or another insult to the airway [(1)].

Hypercapnic respiratory failure is an elevation in $PaCO_2$ greater than 45 mmHg and a pH lower than 7.35 resulting from respiratory pump failure and/or increased carbon dioxide production [(2)].

Hypercapnic respiratory failure is a common problem. For respiratory support in this condition, NIV has been the main modality. However, due to poor mask tolerance, it is inappropriate for certain individuals. When patients are unable to tolerate conventional NIV, HFNC is frequently used to successfully manage hypercapnic respiratory failure since it is more easily tolerated. Nishimura et al.,2016 [3] stated that each person's response to HFNC differed: some people had a drop in RR, while others experienced a decrease in $PaCO_2$.

High Velocity Nasal Insufflation, a type of HFNC that uses a tiny bore nasal cannula to replace larger bore HFNC to create greater gas delivery velocities. With flow rates of thirty-five liters per minute, it can completely clear extrathoracic dead space and in those suffering from acute type II respiratory failure, besides oxygenation support, it may also be able to provide ventilatory assistance [4].

High-Velocity Nasal Insufflation is a type of NIV that doesn't require a face mask and is used to help oxygenate patients experiencing respiratory distress due to pulmonary reasons such as dyspnea, hypoxemia, hypercapnia or non-pulmonary causes of respiratory distress. Hi-VNI has an advantage over HFNC in that, even at 40 l/min, the small-bore cannulas produce higher velocity, can rapidly remove expiratory gas with a high CO2 concentration from dead space in the upper airways. So, a new gas reservoir is produced and reduce the breathing effort. Patients with acute respiratory failure who have higher RR and shorter intervals between breaths for gas exchange can benefit from Hi-VNI [5].

Methods

This is an analytical hospital based cross sectional study that was performed on 74 AECOPD cases presented to Cardiothoracic Minia University Hospital by acute hypercapnic respiratory failure during the period from November 2022 to January 2024. Patients were divided into two groups based on the first line of ventilatory support applied, including NIPPV group (40 patients) and Hi-VNI group (34 patients).

Inclusion criteria:

- All AECOPD patients presented to the emergency room at Cardiothoracic Minia University Hospital by Respiratory acidosis (PaCO2 greater than 45 mmHg and a pH lower than 7.35) [6].
- patients presented to the emergency room on NIV from another hospital.

Exclusion criteria:

- Asthmatic patients.
- End stage cancer.
- Respiratory and cardiac arrest.
- Hemodynamic instability.
- Decreased mental status (GCS <9).
- Left sided heart failure.
- Other causes of hypoventilation as: obesity hypoventilation syndrome, obstructive sleep apnea, neuromuscular diseases and drug overdose.

Ethical consideration:

- The whole study design was approved by the Research Ethics Committee of Faculty of Medicine, Minia University. The ethical number was 538:2022.
- Confidentiality and personal privacy were respected in all levels of the study.
- Patients feel free to withdraw from the study at any time without any consequences.

The following were applied to patients:

- Detailed medical history.
- Thorough clinical examination, both general and local chest examination.
- Routine laboratory tests including complete blood count, renal function tests, liver function tests, C- reactive protein and serum electrolytes.
- Plain Chest Radiographs and Computed Tomography if indicated.
- Analysis of Arterial Blood Gases (ABGs): done by Sensacor ST-200CC including PH, PaO2, PaCO2, bicarbonate concentration (HCO_3). These values were measured on admission, after 1 hour, 2hrs, 6hrs, 24hrs and on discharge.
- Electrocardiogram.
- Echocardiography if needed.

Study interventions:

Patients were randomly assigned to either NIPPV or Hi-VNI. NIPPV was provided by a [AVEA ventilator USER INTERFACE MODULE or Maquet caro AB Servo-a BASE UNIT] with the initial parameters of 10:20 cm

H_2O for the inspiratory positive airway pressure, 5:10 cm H_2O for the expiratory positive airway pressure, and 1.0 for the fractional inspirated oxygen (fiO_2).

Hi-VNI was supplied using a Vapotherm Precision Flow [*Precision Flow Plus, Vapotherm, INC. U.S.A*. device]. The starting flow rate was thirty-five L/min and the temperature adjusted at 35:37°C and a FiO_2 of 1.0.

The goals of both approaches were to increase patient comfort as evaluated by the clinician, relieve respiratory distress by a reduction of RR < 25 breaths / minute and to keep saturation levels over 88% [(7)]. ABG at 0, 1h, 2hrs, 6hrs, 24hrs and on discharge were collected and analyzed. Treatment failure was defined as the need for invasive mechanical ventilation or shift to the other device.

Statistical analysis:

Data were analyzed via SPSS version 26 for windows (SPSS Inc., Chicago, IL, USA).
The Shapiro Walk test was used to determine if the data were normally distributed. Frequencies and relative percentages were used to display the qualitative data. Using Fisher exact and the Chi square test, categorical data was compared. Quantitative data was stated as mean ± standard deviation for parametric, median and range for non-parametric data.

For parametric and non-parametric variables, respectively, the difference between the quantitative variables in 2 related groups was determined using the Paired Sample T test and the Wilcoxon Sign Rank Test.

Every statistical difference between groups was examined using the one-way analysis of variance (ANOVA) and Friedman test.

Each significant statistical comparison a P-value of less than or equal 0.05 suggests a significant difference, p <0.001 a highly significant difference, and P> 0.05 a non-significant difference.

Results

The study was performed on 74 AECOPD cases who were admitted to the Respiratory Intensive Care Unit at Cardiothoracic Minia University Hospital by acute hypercapnic respiratory failure. The involved patients were classified into two groups based on the first line of ventilatory support used, including NIPPV group (40 patients) and Hi-VNI group (34 patients).

As shown in **Figure 1** 27 cases from the total number of NIV group (40 cases) improved and the remaining 13 cases failed. 3 cases out of the 13 failed cases were shifted to Hi-VNI and the remaining 10 cases were intubated. Out of 3 shifted cases, all of them were improved. On the other hand, 22 cases improved from the Hi-VNI group (34 cases), and the other 12 remaining cases failed; 11 cases from the failure group were shifted to NIV while 1 case was intubated. Out of 11 shifted cases, there were 6 cases improved and 5 cases intubated.

By comparing both NIPPV group and HI-VNI group regarding RR on admission, after 1hr, 2hrs, 6hr, 24hrs and on discharge, the results were non-statistically significant different (p value >0.05) (Table 1).
While for intra group comparison, there were statistically significant decline in RR after 1hour, 2hrs, 6hrs, 24hrs and on discharge compared to baseline RR either in NIPPV group or in HI-VNI group (Figure 2).

Regarding PH on admission, after 1hr, 2hrs, 6hrs, 24hrs and on discharge, there were non-statistically significant differences among NIPPV and HI-VNI groups (p value >0.05) (Table 1).
On the other hand, for intra group comparison, there were statistically significant increase in PH after 1hr compared to PH on admission, also after 2hr, 6hrs, 24hrs and on discharge compared to baseline either in NIV group or in HI-VNI group. (Figure 3).

As regards $PaCO_2$ on admission, after 1hr, 2hrs, 6hrs, 24hrs and on discharge, there were non-statistically significant differences among the 2 groups (p value >0.05) (Table 1).

While inside the same group, there were statistically significant decrease in $PaCO_2$ after 1 hour compared to $PaCO_2$ on admission, also after 2hrs, 6hrs, 24hrs and on discharge compared to baseline either in NIPPV group or in HI-VNI group (P value <0.05) (Figure 4).

By comparing both NIPPV group and HI-VNI group regarding PaO_2 on admission, after 1hr, 2hrs, 6hrs, 24hrs and on discharge, the study deduced non-statistically significant differences among the 2 groups (p value >0.05) (Table 1).

On the other hand, there were statistically significant increase in PaO_2 after 1 hour compared to PaO2 on admission, also after 2hrs, 6hrs, 24hrs and on discharge compared to baseline either in NIV group or in HI-VNI group. (P value <0.05). (Figure 5).

By comparing both NIPPV group and HI-VNI group regarding clinical outcomes, table 2 elucidated that there were statistically significant differences regarding transformation to another device and total length of hospital stay in days (p value <0.05) as total duration of hospital admission was more in NIPPV group (mean was 17.5 days) than in HI-VNI group (mean was 15 days). Regarding shift to another device, 3 cases shifted from NIV to HI-VNI (7.5%) compared to 11 cases shifted from HI-VNI to NIV (32.4%). While there were no significant differences among the 2 groups in success rate, duration of device application, need for intubation, duration of invasive mechanical ventilation, duration of ICU stay, intubation after device shift, in-hospital mortality and 30 days mortality (p value >0.05).

Table (1): changes in patient physiologic parameters.

	NIPPV		Hi-VNI		P value
	Mean ±SD	Range	*Mean ±SD*	Range	
RR					
Baseline	36±*9.1*	18:50	34.2±*7.3*	20:50	0.34
1hour	31.3±*8.2*	14:45	29.4±*6.3*	20:45	0.26
2hours	29.6±*9.3*	14:50	27±*7*	16:45	0.19
6hours	27.2±*9.2*	13:50	24.1±*7.3*	14:50	0.12
24hours	23.3±*7.3*	14:42	21±*5.4*	14:35	0.11
On discharge	*16.5*±*3.4*	14:20	*16.7*±*3.7*	15:21	0.8
P value	*<0.001* *		*<0.001* *		
PH					
Baseline	7.21±*0.07*	7.03:7.33	7.23±*0.06*	7.04:7.33	0.33
1hour	7.24±*0.06*	7.06:7.35	7.26±*0.06*	7.06:7.34	0.25
2hours	7.26±*0.08*	7.07:7.53	7.28±*0.07*	7.10:7.39	0.32
6hours	7.29±*0.08*	7.09:7.50	7.29±*0.08*	7.13:7.43	0.88
24hours	7.31±*0.09*	7.07:7.47	7.31±*0.08*	7.11:7.37	0.99
On discharge	7.38±*0.03*	7.35:7.47	7.37±*0.03*	7.35:7.47	0.73
P value	*<0.001* *		*<0.001* *		
PaCO2					
Baseline	76.8±*14.9*	52:115	72.7±*13.3*	49:100	0.22
1hour	69.3±*11.1*	50:100	68.8±*11.6*	48:95	0.87
2hours	67.1±*14.3*	43:110	65.7±*12.8*	41:98	0.67
6hours	64.1±*15.6*	32:112	63.9±*12*	38:96	0.96
24hours	61.7±*18.5*	42:128	62.9±*15.8*	40:103	0.76
On discharge	49.6±*7.3*	36:64	50.9±*5*	41:58	0.43
P value	*<0.001* *		*<0.001* *		
PaO2					
Baseline	71.2±*3.8*	30:112	68±*4.5*	45:98	0.38
1hour	83.6±*3.7*	58:178	84.5±*4.7*	61:121	0.83
2hours	85.2±*4*	60:125	86.8±*5.1*	67:115	0.63
6hours	89.7±*4*	44:151	83.8±*4.5*	61:112	0.17
24hours	87±*5.5*	61:148	81.5±*4.8*	40:120	0.12
On discharge	76.5±*9.2*	67:98	74.5±*2.9*	63:98	0.40
P value	*<0.001* *		*<0.001* *		

_* significant at p value<0.05

NIV: Non-invasive Ventilation. HI-VNI: High Velocity Nasal Insufflation. SD: Standard Deviation. RR: Respiratory Rate. pH: hydrogen ion concentration. $PaCO_2$: partial pressure of carbon dioxide in arterial blood. PaO_2: partial pressure of arterial oxygen.

Table (2) Comparison between the 2 groups as regard clinical outcome

Clinical outcome		Group I NIPPV (N=40)	Group II HI-VNI (N=34)	P value
Success	*Yes* *No*	27(67.5%) 13(32.5%)	22(64.7%) 12(35.3%)	0.8
Duration of device application in hours	*Mean ±SD* *Median (Range)*	63.2±96 6 (2:240)	59.2±67.5 48 (2:168)	0.70
Transformation to another device	*No change* *shift to the alternative device*	37(92.5%) 3(7.5%)	23(67.6%) 11(32.4%)	<0.001*
Intubation	*Yes* *No*	10(25%) 30(75%)	6(17.6%) 28(82.4%)	0.44
Length of IMV	*Mean ±SD* *(Range)*	8.1±5.9 2:16	7.4±2 5:10	0.49
Total length of hospital stay (days)	*Mean ±SD* *(Range)*	17.5±10.6 7:40	15±7.1 9:25	0.03*
Length of ICU admission(days)	*Mean ±SD* *(Range)*	14.8±8.6 7:30	15±7.1 9:25	0.07
Intubation with device after shift		0	5(14.7%)	0.23
In hospital mortality		7(17.9%)	6(17.6%)	0.97
30 days mortality		9(22.5%)	7(20.6%)	0.84

_* significant at p value <0.05.

NIPPV: Non-Invasive Positive Pressure ventilation. HI-VNI: High Velocity Nasal Insufflation. N: Number. SD: Standard Deviation. IMV: Invasive Mechanical Ventilation. ICU: Intensive Care Unit.

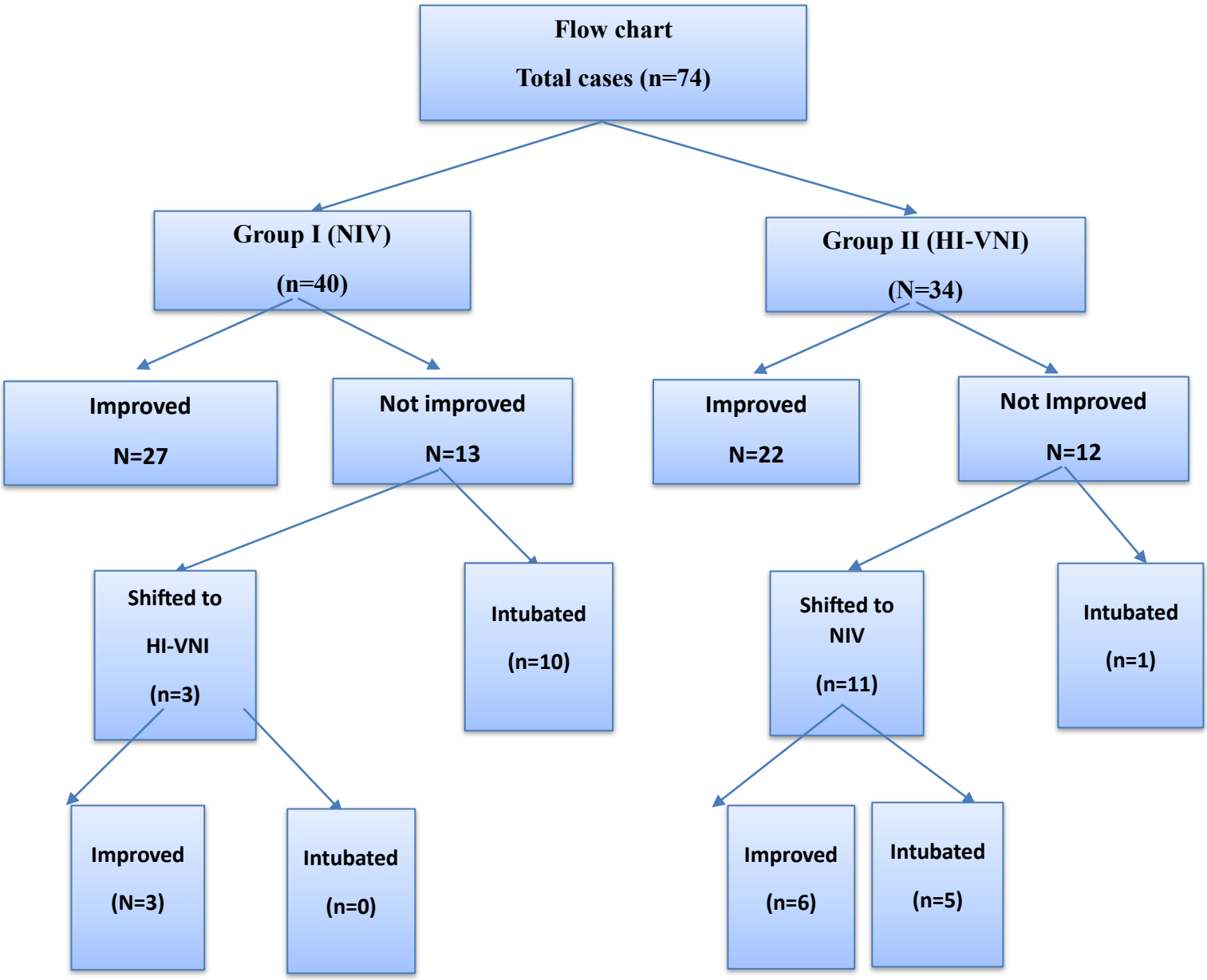

Figure (1) Flow chart of patient enrollment and outcome.

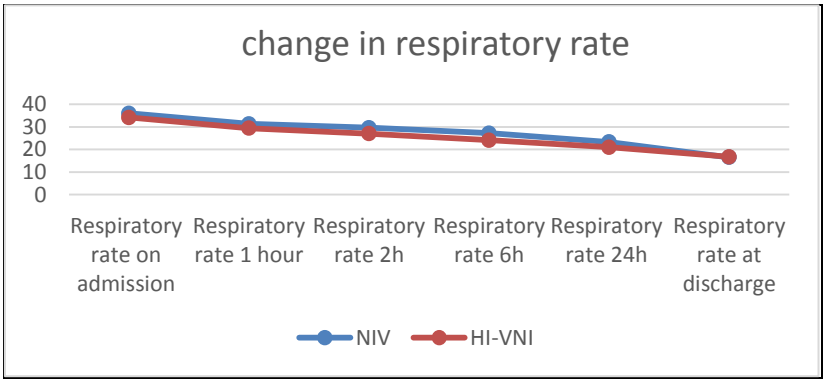

Figure (2) Line chart representing change in respiratory rate in studied groups over time.

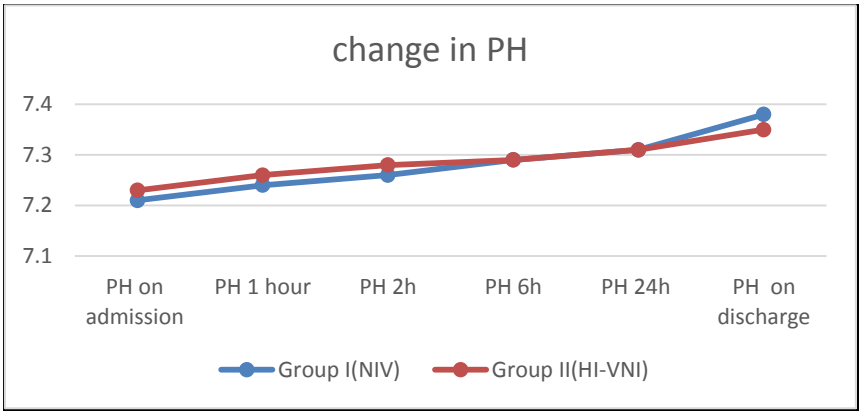

Figure (3) Line chart representing change in PH in studied groups over time.

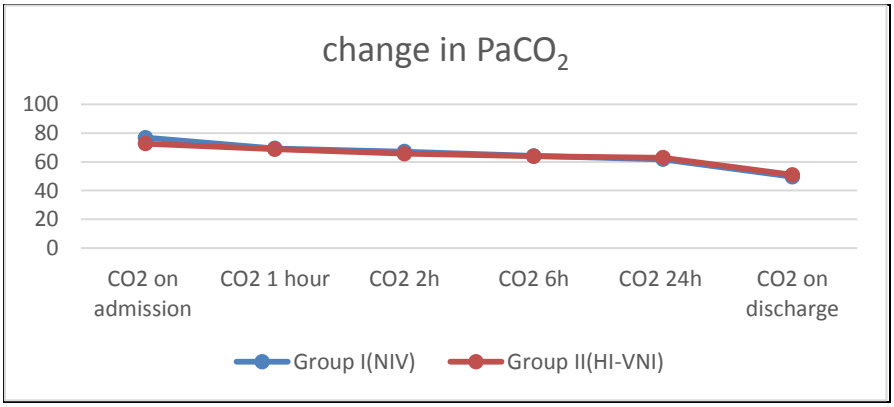

Figure (4) Line chart representing change in $PaCO_2$ in studied groups over time.

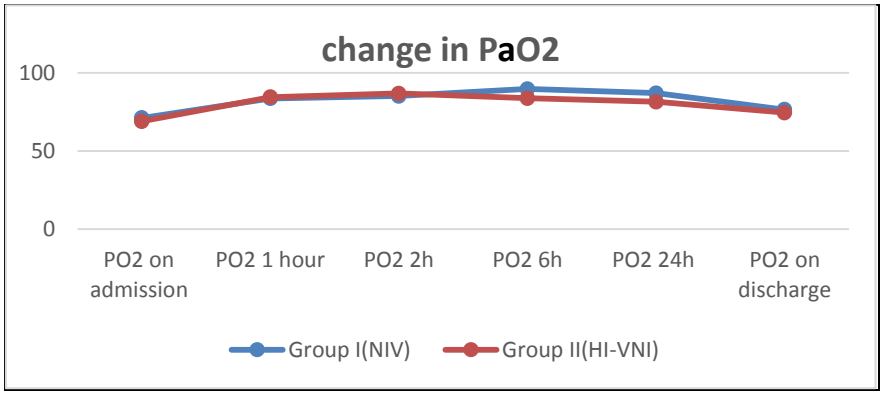

Figure (5) Line chart representing change in PaO2 in studied groups over time.

Discussion

Among the several types of obstructive lung illnesses, COPD is distinguished by airflow limitation and persistent breathing troubles. It is very common among the older people. Due to its widespread occurrence, the disease has a high rate of morbidity and mortality. According to WHO, COPD is the 7th leading cause of disability and the 4th leading cause of death worldwide [8,9].

Patients with COPD have a significantly reduced quality of life as a result of their declining lung function. AECOPD is brought on by environmental variables (air pollution and weather influences) as well as bacterial or viral infections [10].

The symptoms, which include increasing dyspnea, coughing, sputum production, and sputum purulence are its defining characteristics [11]. AECOPD is treated acutely with bronchodilators, steroids, antibiotics, oxygen, and NIV, depending on the severity [12].

NIPPV is currently a commonly utilized and highly efficient treatment for people with respiratory insufficiency. However, this approach somewhat hinders the comfort and compliance of the patients [13].

High Velocity Nasal Insufflation, a type of HFNC that uses a tiny bore nasal cannula to replace larger bore HFNC create greater gas delivery velocities. With flow rates of thirty-five liters per minute, it can completely clear extrathoracic dead space and in those suffering from acute type II respiratory failure, besides oxygenation support, it may also be able to provide ventilatory assistance [14].

In the present study, by comparing both NIPPV group and HI-VNI group regarding RR, PH, $PaCO_2$ and PaO_2 on admission, after 1hr, 2hrs, 6hrs, 24hrs and on discharge, there were no statistically significant differences between the two groups. While for intra group comparison, there were statistically significant decline in RR and $PaCO_2$ after 1hr compared to RR and $PaCO_2$ on admission, also after 2hrs, 6hrs, 24hrs and on discharge compared to baseline either in NIPPV group or in HI-VNI group and there was statistically significant increase in the values of PH and PaO_2 after 1hr compared to PH and PaO_2 on admission, also after 2hrs, 6hrs, 24hrs and on discharge compared to baseline either in NIV group or in HI-VNI group.

These findings are consistent with those of Doshi et al., 2020 [4] who proved that no statistically significant variations were shown between the groups under study regarding RR, PH, $PaCO_2$, PaO_2 on admission, at 60 min and at 240 min. While for intra group comparison, there were statistically significant decline in RR and $PaCO_2$ after 30min compared to RR and $PaCO_2$ on admission, also after 240min either in NIPPV group or in HI-VNI group and there was statistically significant increase in the values of PH and PaO_2 after 60min compared to PH and PaO_2 on admission, also after 240min either in NIV group or in HI-VNI group.

Furthermore, Papachatzakis et al., 2020[15] found no statistically significant changes among the groups under study in PH, $PaCO_2$ and PaO_2 on admission and after 24h.

Added to that, Cortegiani et al., 2020 [16] proved that there was no statistically significant

difference among the investigated groups as regard baseline PaO_2. Also, Cortegiani et al., 2020[16], Jing et al., 2019[17] and Sun et al., 2019[18] revealed that baseline PH and $PaCO_2$ did not statistically significantly differ across the study groups.

The current findings are consistent with McKinstry et al., 2019 [19] who found that there were no statistically significant variations in RR at any particular time point between the groups under study. While for intra group comparison, there were significant decline in RR at different time intervals.

As well, Cong et al, 2019 [20] demonstrated that serum PH and PaO_2 did not statistically significantly differ between the groups under investigation.

By comparing both NIPPV group and HI-VNI group regarding clinical outcomes, the present study found that there were statistically significant differences among the studied groups in transformation to another device because there was worry from the treating staff about switching deteriorating patients from NIV to Hi-VNI as NIV is the gold standard in treating AECOPD. In accordance with these results, Cortegiani A et al., 2020[16] reported that 32.5% of patients treated with HFNT were shifted to NIV, even when a patient's illness was somewhat less severe, but only 7.7% of patients treated with NIV were shifted to HFNT and they explained that from a clinical point of view, a method that allows for a higher and faster decarboxylation may be preferred by the clinician.

Additionally, there were significant variations (p value <0.05) in the duration of hospital admission among the studied groups.

These results contrast with Ali et al., 2023 [22], Fang G et al., 2021[23], Cong L et al., 2019[20] who proved that there was no significant difference between the studied groups as regard duration of hospital admission. This may be due to variability in the severity of exacerbation between the 2 groups that was not assessed in the current study.

While there were non- statistically significant differences among NIPPV group and HI-VNI group in success rate, duration of device application, need for intubation, duration of IMV, duration of ICU stay, intubation after device shift, in-hospital mortality and 30 days mortality (p value >0.05).

In accordance with these results, Doshi PB et al., 2020[21] reported that there was no significant difference among the investigated groups in duration of ICU admission. As well, Papachatzakis Y et al., 2020[15] and Cortegiani A et al., 2020[16] demonstrated that there was no statistically significant difference among the studied groups in mortality rate. Moreover, Sun J et al., 2019 [18] reported that there was no statically significant difference among the studied groups regarding duration of ICU admission and 28-day mortality.

Similarly, Jing G et al., 2019[17] found that there were no significant differences among the studied groups as regard IMV duration, duration of HFNC or NIV, ICU stay and 28 days mortality.

Conclusion

Hi-VNI is effective as a ventilatory support in AECOPD patients presenting with acute type II respiratory failure with non inferior success compared to NIV.

Recommendation:

More research is required to confirm these results.

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