# Evaluation of nasal optiflow device in the management of chronic obstructive pulmonary disease patients with acute excerbations

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***Background*** A new form of therapy that provides humidified high-flow oxygen through a nasal cannula has been introduced recently as an alternative in the treatment of spontaneously ventilating patients with high oxygen requirements.

***Objective*** The aim of the study was to evaluate the efficacy of a nasal optiflow device in the management of chronic obstructive pulmonary disease (COPD) patients with acute exacerbations in comparison with a conventional venturi mask.

***Patients and methods*** Forty-five COPD patients with respiratory failure type II admitted to the RICU at Abbasia Chest Hospital were recruited and divided into two groups: group 1 included 20 randomly selected COPD patients with acute exacerbations connected to a venturi mask; group 2 included 25 randomly selected COPD patients with acute exacerbations connected to nasal high flow (NHF) oxygen with an optiflow system. All patients were subjected to full history taking, thorough clinical examination, and routine laboratory investigations with chest X ray (CXR) and repeated analyses of arterial blood gases (ABGs).

***Results*** No statistically significant difference was observed between the two groups with respect to baseline ABG variables (on admission). In both methods (NHF and venturi mask) there was statistically significant improvement in ABG variables in the form of raised pH, $PO_2$, and $O_2$ saturation and reduced $PCO_2$ when compared with baseline ABG values. Although there was no significant difference in weaning results between the two groups, there was significant decline in $PCO_2$ in the NHF group. There was no significant difference in the outcome and end result between the two groups; successful weaning was achieved in 70% of patients in the venturi group and in 64% of the NHF group, whereas failure was reported in 30% of patients in the venturi group and in 36% in the NHF group.

***Conclusion*** The nasal optiflow device is highly expensive compared with the venturi mask, although both are approximately equally successful in the treatment of COPD patients with respiratory failure type II. *Egypt J Broncho* 2015 9:34–42



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**Keywords:** chronic obstructive pulmonary diseases, nasal high flow, respiratory failure type II, venturi mask

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## Introduction

Respiratory failure may be acute or chronic. Acute hypercapnic respiratory failure develops over minutes to hours, whereas chronic respiratory failure develops over several days or longer [1].

The major treatment for respiratory failure is oxygen therapy, which can be used for a variety of purposes in both chronic and acute patient care. Oxygen is essential for cell metabolism, as tissue oxygenation is essential for all normal physiological functions [2].

Nasal high flow (NHF) is a new respiratory care therapy that aims to meet or exceed the patient's normal inspiratory demand by creating minimal air dilution [2].

It can more accurately deliver prescribed oxygen concentrations at high flows, providing both versatility and continuity of care as patients wean or their condition becomes more acute. This greater flexibility eliminates the need to switch between oxygen delivery systems [3]. It has other benefits as well, such as flushing of the anatomical dead space of the upper airway by the high incoming gas flows. This creates a reservoir of fresh gas available for each and every breath, minimizing the rebreathing of $CO_2$ [4].

In addition, the NHF can deliver optimal humidity, which emulates the balance of temperature and humidity that occurs in healthy lungs, maintaining mucociliary clearance. This is important for patients with secretion problems, such as those with chronic obstructive pulmonary disease (COPD). By delivering optimal humidity, drying of the airway is reduced, which maintains the function of the mucociliary transport system, clearing secretions more effectively and reducing the risk of respiratory infection [5].

## Aim

The aim of this study was to evaluate the efficacy of a nasal optiflow device in the management of COPD patients with acute exacerbations in comparison with a conventional venturi mask (VM).

## Patients and methods

The study was conducted on 45 patients diagnosed with COPD according to GOLD [6], who presented with acute exacerbations and were admitted to the respiratory ICU in Abbasia Chest Hospital during the period between February 2014 and August 2014. All patients were diagnosed (on the basis of clinical and arterial blood findings) as having respiratory failure type II necessitating oxygen therapy and were classified into two groups:

(1) First group included 20 randomly selected COPD patients with acute exacerbations connected to a VM.
(2) Second group included 25 randomly selected COPD patients with acute exacerbations given NHF oxygen by means of an optiflow system.

Inclusion criteria were as follows:

To be included in the study the participants had to be COPD patients with acute exacerbations, with respiratory failure, admitted to the respiratory ICU.

Exclusion criteria were as follows:

(1) Presence of other chest diseases such as bronchial asthma, pulmonary tuberculosis, interstitial lung diseases, pulmonary embolism, and pneumonia.
(2) Presence of any organ failure such as cerebrovascular stroke, heart failure, hepatic cell failure, and renal failure.
(3) Having a disturbed conscious level.

All patients were subjected to the following:

(1) Full history taking, including of their relatives.
(2) Clinical examination, including:
    (a) General and local chest, cardiac, abdominal, and neurological examination.
    (b) Routine laboratory investigations.

These included:

(1) Random blood sugar.
(2) Serum electrolytes.
(3) Kidney and liver function tests.
(4) Complete blood picture.
(5) Plain chest radiography.
(6) ECG.
(7) Repeated arterial blood gases (ABGs).

### Venturi mask

This comes in a kit that includes five to seven interchangeable air entrainment devices used to achieve an inspired oxygen concentration between 24 and 60%, depending on the manufacturer, and flow ranging between 2 and 15 l/min [7].

### The optiflow device

This system basically works with an air oxygen blender allowing from 21 to 100% $FIO_2$ and generates a flow rate up to 60 l/min, but most patients in our study are put on a flow rate of 10 l/min and $FIO_2$ ranging between 35 and 60%. The gas is heated and humidified through an active heated humidifier and delivered through a single limb heated inspiratory circuit (to avoid heat loss and condensation) to the patient through a nasal cannula of large diameter [8].

The study endpoint was weaning success, need for intubation and mechanical ventilation, and occurrence of complications (Fig. 1).

### Statistical analysis

The collected data were revised, coded, tabulated, and analyzed with an IBM computer using statistical package for the social sciences (SPSS, version 12; SPSS Inc., Chicago, Illinois, USA). Data were presented and appropriately analyzed according to the type of data obtained for each parameter.

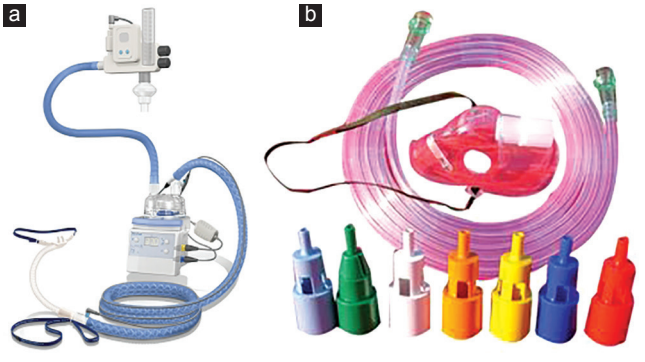
*Descriptive statistics*

(1) The mean ± SD, median, and minimum and maximum values (range) were determined for quantitative variables.
(2) Qualitative variables were presented as number and percentage.

*Analytical statistics*

(1) The $\chi^2$-test was used to compare qualitative variables between two groups.
(2) The unpaired *t*-test was used to compare quantitative variables in parametric data (SD < 50% mean).
(3) The paired *t*-test was used to compare quantitative variables in the same group.
(4) The Spearman correlation coefficient test was used to rank variables positively or inversely [9].

**Fig. 1**




(a) Nasal optiflow device. (b) Venturi mask.

*P-value: level of significance*

*P* values greater than 0.05 were considered nonsignificant (NS). *P* values less than 0.05 were considered significant (S). *P* values less than 0.01 were considered highly significant (HS).

## Results

This study was conducted on 45 COPD patients who presented with acute exacerbation necessitating oxygen therapy. Patients were classified into two groups; the first group included 20 patients connected to a VM, whereas the second group included 25 patients connected to NHF oxygen by means of an optiflow device.

There was no statistically significant difference between the two studied groups as regards general data. The mean age of the VM group was 60.7 years (about 75% of patients were male and 25% were female), whereas the mean age of the NHF group was 60 years (about 92% of patients were male and 8% were female) (Table 1).

There were no statistically significant differences between the studied groups as regards general examination for blood pressure, cyanosis, jaundice, pulse, lower limb (LL) edema, and neck veins.

There were no statistically significant differences between the studied groups as regards laboratory data for random blood sugar, hemoglobin, total leukocytic count (TLC), creatinine, albumin, Na, K, urea, serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), total bilirubin, and total protein.

No statistically significant differences were found between the studied groups as regards blood gases at admission, on the basis of the unpaired *t*-test (Table 2).

No statistically significant differences were found between the studied groups as regards blood gases on day 1 on the basis of the unpaired *t*-test (Table 3).

PH was seen to be increased and $PCO_2$ to be reduced, whereas $PO_2$ and $SO_2$ were increased, with highly significant statistical difference, on the paired *t*-test (Table 4).

pH, $PO_2$, and $SO_2$ were seen to be increased, with highly significant statistical difference, but there was no significant change in $PCO_2$, on the paired *t*-test (Table 5).

No statistically significant difference was seen between the two groups as regards blood gases on day 2 on using the unpaired *t*-test.

pH, $PO_2$, $SO_2$, $HCO_3$, and base excess (BE) were raised with highly significant statistical difference, whereas $PCO_2$ was reduced with statistically significant difference, on using the paired *t*-test (Table 6).

**Table 1 Comparison between the studied groups as regards general data**

| Variables | *N* (%) | | Test | *P* |
|---|---|---|---|---|
| | VM (*n* = 20) | NHF (*n* = 25) | | |
| Age (mean ± SD) | 60.7 ± 7 | 60 ± 5 | Independent *t*-test | >0.05 (NS) |
| Sex | | | | |
| Male | 15 (75) | 23 (92) | Fisher test | >0.05 (NS) |
| Female | 5 (25) | 2 (8) | | |
| Occupation | | | | |
| No work | 3 (15) | 6 (24) | $\chi^2$-Test | >0.05 (NS) |
| Manual | 10 (50) | 17 (68) | | |
| House wife | 5 (25) | 2 (8) | | |
| Clerk | 2 (10) | 0 | | |
| Special habits | | | | |
| No | 4 (20) | 2 (8) | $\chi^2$-Test | >0.05 (NS) |
| Current smoking | 9 (45) | 15 (60) | | |
| Ex-smoker | 7 (35) | 8 (32) | | |

NHF, nasal high flow; VM, venturi mask.

**Table 2 Comparison between the studied groups as regards blood gases on admission**

| Variables | VM (*n* = 20) | NHF (*n* = 25) | *T* | *P* |
|---|---|---|---|---|
| pH | 7.28 ± 0.07 | 7.30 ± 0.05 | 1.177 | >0.05 (NS) |
| $PCO_2$ | 80.3 ± 10 | 72.5 ± 12 | 1.7 | >0.05 (NS) |
| $PO_2$ | 38.1 ± 8 | 33.7 ± 7.7 | 1.8 | >0.05 (NS) |
| $HCO_3$ | 34.5 ± 7 | 34.4 ± 4 | 0.6 | >0.05 (NS) |
| BE | 8.6 ± 2.3 | 7.6 ± 1.5 | 0.7 | >0.05 (NS) |
| $SO_2$ | 0.62 ± 0.3 | 0.57 ± 0.13 | 1.2 | >0.05 (NS) |

NHF, nasal high flow; VM, venturi mask.

**Table 3 Comparison between the studied groups as regards blood gases on day 1**

| Variables | VM (*n* = 20) | NHF (*n* = 25) | *T* | *P* |
|---|---|---|---|---|
| pH | 7.32 ± 0.08 | 7.33 ± 0.05 | 0.557 | >0.05 (NS) |
| $PCO_2$ | 73.7 ± 12 | 69.4 ± 11 | 1.2 | >0.05 (NS) |
| $PO_2$ | 57.3 ± 7 | 61 ± 5.6 | 1.3 | >0.05 (NS) |
| $HCO_3$ | 35.7 ± 3 | 35.4 ± 5 | 0.06 | >0.05 (NS) |
| BE | 9.3 ± 2 | 9.2 ± 1.8 | 0.09 | >0.05 (NS) |
| $SO_2$ | 0.85 ± 0.2 | 0.86 ± 0.1 | 0.2 | >0.05 (NS) |

NHF, nasal high flow; VM, venturi mask.

**Table 4 Comparison between the results at admission and on day 1 as regards blood gases in the venturi mask group**

| Variables | Admission | Day 1 | *T* | *P* |
|---|---|---|---|---|
| pH | 7.28 ± 0.07 | 7.32 ± 0.08 | 2.699 | <0.05 (S) |
| $PCO_2$ | 80.3 ± 10 | 73.7 ± 12 | 2.1 | <0.05 (S) |
| $PO_2$ | 38.1 ± 8 | 57.3 ± 7 | 7.3 | <0.001 (HS) |
| $HCO_3$ | 34.5 ± 7 | 35.7 ± 3 | 0.8 | >0.05 (NS) |
| BE | 8.6 ± 2.3 | 9.3 ± 2 | 0.6 | >0.05 (NS) |
| $SO_2$ | 0.62 ± 0.3 | 0.85 ± 0.2 | 7 | <0.001 (HS) |

HS, highly significant; S, significant.

**Table 5 Comparison between the results at admission and on day 1 as regards blood gases in the nasal high flow group**

| Variables | Admission | Day 1 | *T* | *P* |
|---|---|---|---|---|
| pH | 7.30 ± 0.05 | 7.33 ± 0.05 | 3.727 | <0.001 (HS) |
| $PCO_2$ | 72.5 ± 12 | 69.4 ± 11 | 1.7 | >0.05 (NS) |
| $PO_2$ | 33.7 ± 7.7 | 61 ± 5.6 | 10 | <0.001 (HS) |
| $HCO_3$ | 34.4 ± 4 | 35.4 ± 5 | 1.2 | >0.05 (NS) |
| BE | 7.6 ± 1.5 | 9.2 ± 1.8 | 1.5 | >0.05 (NS) |
| $SO_2$ | 0.57 ± 0.13 | 0.86 ± 0.1 | 9.7 | <0.001 (HS) |

HS, highly significant.

**Table 6 Comparison between the results at admission and on day 2 in the venturi mask group**

| Variables | Admission | Day 2 | *T* | *P* |
|---|---|---|---|---|
| pH | 7.28 ± 0.07 | 7.35 ± 0.07 | 4.858 | <0.001 (HS) |
| $PCO_2$ | 80.3 ± 10 | 72 ± 7 | 2.4 | <0.05 (S) |
| $PO_2$ | 38.1 ± 8 | 60.3 ± 5 | 8 | <0.001 (HS) |
| $HCO_3$ | 34.5 ± 7 | 38.8 ± 4 | 2.2 | <0.05 (S) |
| BE | 8.6 ± 2.3 | 13.5 ± 6 | 3.4 | <0.001 (HS) |
| $SO_2$ | 0.62 ± 0.3 | 0.88 ± 0.2 | 7.8 | <0.001 (HS) |

HS, highly significant; S, significant.

pH was seen to be increased, $PCO_2$ to be reduced, and $SO_2$, $PO_2$, and base excess (BE) to be increased with statistically significant difference on using the paired *t*-test (Table 7).

$PCO_2$ was found to be higher in the VM group with statistically significant difference between the two groups on using the unpaired *t*-test; there was no significant difference as regards other variables (Table 8).

$PCO_2$ was found to be reduced, whereas pH, $PO_2$, BE, and $SO_2$ were found to be increased, with statistically significant difference on using the paired *t*-test (Table 9).

$PCO_2$ was found to be reduced with statistically significant difference, whereas pH, $PO_2$, and $SO_2$ were found to be increased with highly statistically significant difference, on using the paired *t*-test (Table 10).

No statistically significant difference was found between the two groups as regards blood gases 1 h after weaning on a nasal prong, on using the unpaired *t*-test (Table 11).

No statistically significant difference was found between the two groups as regards the outcome, on using the $\chi^2$-test. In the VM group 14 (70%) patients were successfully weaned on a nasal prong, whereas five (25%) patients were mechanically ventilated and one (5%) patient was put on noninvasive mechanical ventilation; two (10%) patients from those ventilated patients died. In the NHF group 16 (64%) patients were successfully weaned on a nasal prong, whereas five (20%) patients were mechanically ventilated and four (16%) were put on noninvasive mechanical ventilation. One (4%) patient from those ventilated died (Table 12).

**Table 7 Comparison between the results at admission and on day 2 in the nasal high flow group**

| Variables | Admission | Day 2 | *T* | *P* |
|---|---|---|---|---|
| pH | 7.30 ± 0.05 | 7.34 ± 0.07 | 4.686 | <0.001 (HS) |
| $PCO_2$ | 72.5 ± 12 | 62.6 ± 5 | 2.4 | <0.05 (S) |
| $PO_2$ | 33.7 ± 7.7 | 57.9 ± 4 | 11.3 | <0.001 (HS) |
| $HCO_3$ | 34.4 ± 4 | 35.6 ± 7 | 1.5 | >0.05 (NS) |
| BE | 7.6 ± 1.5 | 9.6 ± 3 | 2.3 | <0.05 (S) |
| $SO_2$ | 0.57 ± 0.13 | 0.86 ± 0.3 | 10 | <0.001 (HS) |

HS, highly significant; S, significant.

**Table 8 Comparison between both groups as regards end results of the study**

| Variables | VM (*n* = 20) | NHF (*n* = 25) | *T* | *P* |
|---|---|---|---|---|
| PH | 7.4 ± 0.07 | 7.39 ± 0.04 | 0.265 | >0.05 (NS) |
| $PCO_2$ | 66.8 ± 11 | 55.6 ± 7 | 2 | <0.05 (S) |
| $PO_2$ | 62.6 ± 7 | 60.79 ± 5.19 | 0.818 | >0.05 (NS) |
| $HCO_3$ | 41.4 ± 8 | 35 ± 5.5 | 1.8 | >0.05 (NS) |
| BE | 15.6 ± 6 | 9.5 ± 3 | 1.9 | >0.05 (NS) |
| $SO_2$ | 0.91 ± 0.02 | 0.89 ± 0.02 | 1.3 | >0.05 (NS) |

NHF, nasal high flow; S, significant; VM, venturi mask.

**Table 9 Comparison between results of admission and the end results of the study in the venturi mask group**

| Variables | Admission | Weaning | *T* | *P* |
|---|---|---|---|---|
| pH | 7.28 ± 0.07 | 7.4 ± 0.07 | 10.022 | <0.001 (HS) |
| $PCO_2$ | 80.3 ± 10 | 66.8 ± 11 | 2 | <0.05 (S) |
| $PO_2$ | 38.1 ± 8 | 62.6 ± 7 | 10 | <0.001 (HS) |
| $HCO_3$ | 34.5 ± 7 | 41.4 ± 8 | 1.9 | >0.05 (NS) |
| BE | 8.6 ± 2.3 | 15.6 ± 6 | 2.3 | <0.05 (S) |
| $SO_2$ | 0.62 ± 0.3 | 0.91 ± 0.02 | 8.9 | <0.001 (HS) |

HS, highly significant; S, significant.

**Table 10 Comparison between the results of admission and the end results of the study in the nasal high flow group**

| Variables | Admission | Weaning | *T* | *P* |
|---|---|---|---|---|
| pH | 7.30 ± 0.05 | 7.39 ± 0.04 | 6.528 | <0.001 (HS) |
| $PCO_2$ | 72.5 ± 12 | 55.6 ± 7 | 2.4 | <0.05 (S) |
| $PO_2$ | 33.7 ± 7.7 | 60.79 ± 15.9 | 4.8 | <0.001 (HS) |
| $HCO_3$ | 34.4 ± 4 | 35 ± 5.5 | 0.13 | >0.05 (NS) |
| BE | 7.6 ± 1.5 | 9.5 ± 3 | 0.5 | >0.05 (NS) |
| $SO_2$ | 0.57 ± 0.13 | 0.89 ± 0.02 | 4 | <0.001 (HS) |

HS, highly significant; S, significant.

**Table 11 Comparison between both groups on nasal prong 1 h after weaning**

| Variables | VM (*n* = 20) | NHF (*n* = 25) | *T* | *P* |
|---|---|---|---|---|
| pH | 7.41 ± 0.04 | 7.38 ± 0.03 | 1.7 | >0.05 (NS) |
| $PCO_2$ | 59.6 ± 11 | 62.4 ± 7 | 0.7 | >0.05 (NS) |
| $PO_2$ | 62.6 ± 5 | 60.4 ± 3 | 0.7 | >0.05 (NS) |
| $HCO_3$ | 36.9 ± 4 | 36.1 ± 6 | 0.9 | >0.05 (NS) |
| BE | 12.2 ± 3 | 10.8 ± 3 | 0.4 | >0.05 (NS) |
| $SO_2$ | 0.90 ± 0.04 | 0.89 ± 0.05 | 0.9 | >0.05 (NS) |

NHF, nasal high flow; VM, venturi mask.

A highly significant statistical difference was found between the two groups regarding the duration of stay in the ICU on using the unpaired *t*-test. The mean duration was longer in the VM group (3.1 ± 1.25 days) compared with the NHF group (1.52 ± 1.1 days) (Table 13).

No significant correlation was found between $FIO_2$ and flow of $O_2$ of the VM versus blood gases on the Spearman correlation test (Table 14).

No significant correlation was found between $FIO_2$ and flow of $O_2$ of NHF versus blood gases on the Spearman correlation test (Table 15).

## Discussion

Recently, a new therapy that provides humidified high-flow oxygen through a nasal cannula (HFNC) has been introduced as an alternative for the treatment of spontaneously ventilating patients with high oxygen requirements [3].

Our study was conducted in the respiratory ICU of Abbasia Chest Hospital and included 45 patients admitted with an acute exacerbation of COPD with respiratory failure, who were divided into two groups: the first group included 20 patients who were connected to a VM, whereas the second group included 25 patients who were connected to NHF oxygen by means of an optiflow device.

The first group included 16 male and four female patients with a mean age of 60.7 ± 7 years, but the second group included 23 male and two female patients with a mean age of 60 ± 5 years, with no statistically significant difference between the two groups regarding age and sex. This result was in agreement with that of Charles *et al*. [10] who reported a mean age of 69.4 ± 9.2 years in their study. Lenglet *et al*. [11] reported a median age of 64 (46–84.7) years in their study.

Similar results were also seen in other studies such as those by Sztrymf *et al*. [12] and Roca *et al*. [13], who reported mean ages of 59 (38–73) and 57 (40–70) years, respectively.

The mean age in this study was higher than that in the study by Bräunlich *et al*. [14], who reported a mean age of 18–64 (32.8 ± 13.6) years. This difference may be because of the different diagnosis of patients [COPD and interstitial pulmonary fibrosis) in the study by Bräunlich and colleagues.

In the current study, an analysis of the ABGs during conventional oxygen therapy (VM) showed that the mean pH was significantly increased from 7.28 (7.28 ± 0.07) to 7.40 (7.40 ± 0.07), $PaO_2$ was increased significantly from 38.1 (38.1 ± 8) to 62.6 (62.6 ± 7), and $O_2$ saturation was increased significantly from 62 (0.62 ± 0.3) to 91 (0.91 ± 0.02)%, whereas $PaCO_2$ was significantly reduced from 80.3 (80.3 ± 10) to 66.8 (66.8 ± 11). During NHF, the analysis of ABGs showed that the mean pH was increased significantly from 7.30 (7.28 ± 0.05) to 7.39 (7.39 ± 0.04), $PaO_2$ was increased significantly from 33.7 (33.7 ± 7.7) to 60.79 (60.79 ± 15.9), and $O_2$ saturation was increased significantly from 57 (0.57 ± 0.13) to 89 (0.89 ± 0.02)%; $PaCO_2$ was reduced significantly from 72.5 (72.5 ± 12) to 55.6 (55.6 ± 0.7). Thus, it is clear that $PCO_2$ was

**Table 12 Comparison between both groups as regards outcome**

| Variables | *N* (%) | | Test | *P* |
|---|---|---|---|---|
| | VM (*n* = 20) | NHF (*n* = 25) | | |
| Outcome details | | | | |
| Nasal prong | 14 (70) | 16 (64) | Fisher exact test | >0.05 (NS) |
| Mechanical ventilation | 5 (25) | 5 (20) | | |
| Noninvasive mechanical ventilation | 1 (5) | 4 (16) | | |
| Death | 2 (10) | 1 (4) | | |
| Weaning outcome | | | | |
| Failed | 6 (30) | 9 (36) | Fisher exact test | >0.05 (NS) |
| Success | 14 (70) | 16 (64) | | |

NHF, nasal high flow; VM, venturi mask.

**Table 13 Comparison between both groups as regards the duration of stay in the ICU**

| Variables | VM (*n* = 20) | NHF (*n* = 25) | *T* | *P* |
|---|---|---|---|---|
| Duration ICU | 3.1 ± 1.25 | 1.52 ± 1.1 | 4.533 | <0.001 (HS) |

HS, highly significant; NHF, nasal high flow; VM, venturi mask.

**Table 14 Correlation between $FIO_2$ and flow with arterial blood gas parameters in the venturi mask group**

| Variables | $FIO_2$ | | Flow | |
|---|---|---|---|---|
| | *R* | *P*-value | *R* | *P*-value |
| Average pH | –0.176 | 0.459 | –0.256 | 0.277 |
| Average $PCO_2$ | 0.242 | 0.304 | 0.358 | 0.121 |
| Average $PO_2$ | 0.182 | 0.443 | 0.400 | 0.080 |
| Average $HCO_3$ | 0.104 | 0.664 | 0.094 | 0.692 |
| Average BE | 0.052 | 0.828 | 0.058 | 0.808 |
| Average $SO_2$ | 0.034 | 0.887 | 0.170 | 0.474 |

**Table 15 Correlation between $FIO_2$ and flow with arterial blood gas parameters in the nasal high flow group**

| Variables | $FIO_2$ | | Flow | |
|---|---|---|---|---|
| | *R* | *P*-value | *R* | *P*-value |
| Average pH | –0.279 | 0.176 | 0.03 | 0.885 |
| Average $PCO_2$ | 0.072 | 0.732 | 0.245 | 0.238 |
| Average $PO_2$ | 0.14 | 0.504 | 0.137 | 0.512 |
| Average $HCO_3$ | –0.049 | 0.814 | 0.388 | 0.056 |
| Average BE | –0.14 | 0.503 | 0.369 | 0.07 |
| Average $SO_2$ | –0.01 | 0.962 | –0.057 | 0.788 |

significantly higher in the VM group than in the NHF group. In contrast, there was no significant difference between the two groups with respect to pH, $PO_2$, and $O_2$ saturation.

These results were in agreement with those of Makowski *et al.* [15], who evaluated the efficacy of a NHF device and enrolled 55 (75.93%) patients; 42 patients with respiratory failure type I and 13 (24.07%) patients with respiratory failure type II. They reported that NHF was associated with significant decline in $PCO_2$ only after 3 days ($P < 0.05$), with significant improvement in $O_2$ saturation, $PaO_2$, and significantly increased pH ($P < 0.05$).

Sztrymf *et al.* [16] reported significant increase in $PaO_2$ in 38 patients with acute respiratory failure after 1 h with NHF in comparison with baseline (141 ± 106 vs. 95 ± 40 mmHg, respectively; $P = 0.009$).

Peters *et al.* [17] studied 50 ICU patients with hypoxemic respiratory distress using NHF (including 12 COPD patients) with pH more than 7.28 and $PCO_2$ less than 65 mmHg and found a significant increase in mean $O_2$ saturations from 89.1 to 94.7% ($P < 0.001$).

These results were in agreement with those of Lenglet *et al.* [11], whose study was conducted on 17 patients with acute respiratory failure to evaluate the efficacy of NHF in Emergency Department of University Hospital (France). They found that $PaO_2$ increased significantly from 61 (56–74) to 129 (96–194) mmHg, and $O_2$ saturation increased significantly from 90 (88.5–94) to 97 (92.5–100)% ($P < 0.001$). However, in contrast to our study there were no significant changes between the baseline value and that after using NHF with regard to pH [7.40 (7.35–7.44) vs. 7.42 (7.35–7.44), respectively] and $PaCO_2$ [40 (34.5–47) vs. 40 (35.5–46) mmHg, respectively]. This difference might be because all patients in the study by Lenglet and colleagues had respiratory failure type I.

Parke *et al.* [18] evaluated NHF oxygen versus usual oxygen therapy and demonstrated that mean $PaCO_2$ was significantly lower in the NHF group (NHF 39.75 mmHg group vs. 41.25 mmHg usual care, $P = ¼0.03$); however, in contrast to our study, $O_2$ saturation was higher in the usual oxygen therapy group compared with the NHF group in 340 postcardiac surgical patients over 14 months in the cardiothoracic and vascular ICU (New Zealand). This difference might be because of the unrecognized oxygen devices used other than NHF.

Similar findings were obtained by Bräunlich *et al.* [14] in a study conducted in University Hospital of Leipzig (Germany). They found that NHF was associated with significant fall in $PCO_2$, from 55.65 ± 0.81 to 50.48 ± 0.69 mmHg in 20 COPD patients and from 51.54 ± 0.7 to 47.93 ± 0.53 mmHg in 20 interstitial pulmonary fibrosis patients with hypercapnia.

In contrast to our study, there was no significant change between the NHF and VM groups as regards $O_2$ saturation. Sarkisian-Donovan *et al.* [19] reported that NHF was associated with significantly increased $O_2$ saturation, from 88 (78–95) to 97 (90–100)% ($P = 0.000004$), when compared with traditional oxygen therapy (VM or nonrebreathing mask) in 29 patients with respiratory insufficiency. This difference may be due to unclear variable adjustment of flow and $FIO_2$ or frequent displacement of the mask.

Taft *et al.* [20] compared NHF oxygen versus conventional oxygen therapy (including nasal cannula, VM, face mask, and nonrebreathing mask) in 49 patients with impending respiratory failure and found that NHF was associated with significant improvement in oxygenation, as $O_2$ saturation on conventional oxygen therapy increased to 88.9 ± 4.98 versus 96.5 ± 2.78% on NHF oxygen ($P < 0.001$). This difference may be because most patients had respiratory failure type I.

Roca *et al.* [21] compared NHF oxygen with a conventional VM in 10 ICU patients with respiratory failure. An analysis of ABG after 30 min on oxygen therapy revealed the following values between VM and HFNC, respectively: mean pH 7.40 (7.37–7.46) versus 7.43 (7.37–7.48); $PaO_2$ 107 (69–145) versus 195 (177–243); $PaCO_2$ 39 (33–47) versus 38 (34–46); $HCO_3$ 23.5 (20.3) versus 23.5 (21.7–29.0); and $O_2$ saturation 96 (91–98) versus 99 (98–99). There was no statistical difference in $PCO_2$ ($P = 0.718$); NHF was associated with significant increase in $O_2$ saturation ($P = 0.012$), but this study was similar to ours in that there was no statistical difference in pH ($P = 0.168$). This difference may be explained by the relatively small number of patients upon whom this study was conducted (only 10 patients). Idone *et al.* [22] conducted a study on 35 patients (18 NHF and 17 VM) needing high-flow oxygen in Università Cattolica del Sacro Cuore (Roma, Italy) to compare NHF with VM and noted that oxygen desaturations were more frequent with VM. This difference was explained by intolerance and frequent displacement of the VM in their study.

Also, Antonicelli *et al.* [23], whose study was conducted on 75 postextubated critically ill patients to compare NHF (40 patients on NHF) with VM (35 patients on VM) in 'Agostino-Gemell' University Hospital (Rome,

Italy), reported that $PO_2$ was higher in the NHF group than in the VM group (317 ± 78 vs. 253 ± 84 at 24 h; $P < 0.01$). Oxygen desaturations were more frequent with the VM than with NHF, but $PaCO_2$ was similar in the two groups, with no statistical difference. This difference was explained by the fact that discomfort and interface displacement were more frequent with VM than with NHF in their study (70 vs. 30% patients; $P < 0.01$).

The study by Riessen *et al*. [24], which enrolled 14 patients with hypoxic respiratory failure to compare NHF oxygen with conventional oxygen therapy via a VM or noninvasive ventilation (NIV) in University Hospital Tübingen (Germany) using a $FIO_2$ of 0.6, reported that there was significant increase in $PO_2$ that was highest under NIV (129 ± 38 mmHg), followed by NHF (101 ± 34 mmHg; $P < 0.01$ vs. NIV) and finally VM (85 ± 21 mmHg), with no significant difference in $PCO_2$. However, similar to our study, there was no significant difference in pH between the three groups. This difference might be because patients had respiratory failure type I.

Also in contrast to our study is that by Sztrymf *et al*. [12], who reported that NHF was associated with a significant increase in oxygen saturation as measured by pulse oximetry [93.5 (90–98.5) vs. 98.5 (95.5–100)%; $P = 0.0003$], significantly increased $PaO_2$ [from 65.5 (53.5–83.5) to 114.5 (72.5–192) mmHg; $P = 0.001$], and moderately increased $PaCO_2$ [from 39.5 (32.5–42.5) to 43 (36–46.5) mmHg; $P = 0.005$]. However, it is similar to ours in that there was no significant change in pH in 20 patients with acute respiratory failure in the ICU on comparing NHF oxygen with conventional oxygen therapy. This difference may be because of the inefficacy of unrecognized oxygen therapy and because patients might have had respiratory failure type I.

In the current study, failure in weaning was seen in six (30%) patients in the first group (VM); five (25%) patients required mechanical ventilation and one (5%) patient required noninvasive mechanical ventilation (NIV). Among them two (10%) patients died. In the second group (NHF), failure in weaning was seen in nine (36%) patients; five (20%) patients required mechanical ventilation and four (16%) patients required noninvasive mechanical ventilation. Among them one (4%) patient died. Successful weaning was seen in 14/20 (70%) patients of the first group (VM) and in 16/25 (64%) patients in the second group (NHF), with no significant difference between the two groups.

These results were in agreement with those of Sztrymf *et al*. [16], in whose study nine of 38 (23.5%) patients failed on NHF and required invasive mechanical ventilation.

In addition, in the study by Sztrymf *et al*. [12] six of 20 (30%) patients were intubated and three patients died in the ICU (mortality rate 15%).

But these results were better than those of Lenglet *et al*. [11], in whose study in university hospital's emergency department 10/17 (59%) patients were successfully weaned from HFNC; however, seven (41%) patients required invasive mechanical ventilation and six (35%) patients died. This difference might be explained by the uncooperation and intolerance of patients in their study.

Also Roca *et al*. [21] found that 50% (5/10) of the patients using nasal optiflow devices required intubation. This difference may be because of the relatively small number of patients upon which this study was based.

In the study by Sarkisian-Donovan *et al*. [19] and Taft *et al*. [20] no patients using high-flow oxygen therapy required noninvasive or invasive ventilation. This difference may be because our patients had respiratory failure type II and were prone to developing severe hypercapnia and respiratory acidosis or to have a disturbed conscious level and hence require intubation and mechanical ventilation.

As regards the duration of stay in the ICU, in our study a significantly long duration was seen in the VM group [3.1 (3.1 ± 1.25) days] compared with the NHF group [1.52 (1.52 ± 1.1) days].

The length of ICU stay in this study is nearly similar to that seen in the study by Peters *et al*. [17], who found that the median duration of stay among patients with NHF was 1.25 (range 0.8–6) days. Our results were also similar to those of Sztrymf *et al*. [12], who saw a median duration of stay among patients on NHF of 1.04 (0.7–5) days or 26.5 (17–121) h.

The length of stay of patients on NHF in the study by Sztrymf *et al*. [16] was longer than that of our study, with a mean duration of 2.8 (2.8 ± 1.8) days with a maximum of 7 days. This difference may be because of the severe condition of the patients included in their study.

The length of stay of patients with NHF was 0.6 (0.17–1.4) days or 13.5 (4–34.5) h in the study by Lenglet *et al*. [11]. This difference may be because their study was conducted in the emergency department.

In the current study, the most important complication in patients with NHF was the intolerance to NHF, which was seen in four (16%) patients due to the heavy circuit of the device and high temperature of the

humidifier (37°C, 44 mg/l). The other complications that occurred with both devices, which were the causes of failure and intubation, were similar, and included disturbed conscious level, elevated $CO_2$ retention, progressive hypoxia, and greater respiratory distress, with no statistically significant differences between the two groups.

These findings are similar to those of Sarkisian-Donovan *et al*. [19], who reported that one patient required a reduction in the temperature of the device to 36°C.

Roca *et al*. [13] reported that one patient found the gas temperature to be too high.

These findings were in contrast to those of Richard *et al*. [25] whose study was conducted on 20 patients with respiratory failure in the University Department of Respiratory Medicine, St Vincent's Hospital (Ireland). They found that two patients refused the VM because of discomfort and intolerance to the mask. This difference may be explained by the optimal humidity associated with NHF.

Idone *et al*. [22] reported that there was an improvement in discomfort with NHF, particularly with respect to dryness of the mouth. Oxygen desaturation and interface displacement requiring an intervention were more frequent with the VM. This difference may be attributed to the optimal humidity associated with NHF.

In this study, there was no significant correlation between $FIO_2$ and flow of $O_2$ versus the change in blood gases in the VM group or in the NHF group.

The result in this study was in contrast to those of Bräunlich *et al*. [14] who conducted their study in the University of Leipzig (Germany) on 16 COPD patients and found that $PCO_2$ decreases with NHF rate, as high-flow nasal prong leads to improved $PCO_2$ in comparison with low-flow nasal prong. It was suggested that $PCO_2$ improvement was more likely to be caused by constant flushing of the upper respiratory tract.

Therefore, in the present study, despite the high cost, heavy circuit, and the need for periodic examination, the nasal optiflow device achieved a success rate of 64%, which is approximately similar to that of the VM, which had a success rate of 70%, considering that the nasal optiflow device and the VM have the same efficacy in the management of COPD patients with respiratory failure type II.

## Conclusion

(1) Despite the high cost, heavy circuit, and need for periodic examination, the nasal optiflow device achieved a success rate of 64% in the management of COPD patients with respiratory failure type II, which is approximately similar to that of the VM, which achieved a success rate of 70%.
(2) The nasal optiflow device is not indicated for patients with unstable COPD or for patients with acute hypercapnia and pH of less than or equal to 7.25 because of the higher probability of NHF failure.
(3) The nasal optiflow device is highly costly compared with the VM because of its high price and the need for periodic examination of the device by an experienced engineer and the need for changing the oxygen sensor every 2 years. This high cost makes it unsuitable for a poor country like Egypt, especially as its success rate is almost similar to that of the VM, which is cheaper.

The main benefit in the clinical use of NHF is the effective humidification, although it is associated with a variable degree of inadequate tolerance due to heaviness of its circuit and high temperature of the humidification (37°C, 44 mg/l).

## Acknowledgements

### Conflicts of interest

There are no conflicts of interest.

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