ORIGINAL ARTICLE

Nasal High-Flow versus Venturi Mask Oxygen Therapy after Extubation

Effects on Oxygenation, Comfort, and Clinical Outcome

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Abstract

Rationale: Oxygen is commonly administered after extubation. Although several devices are available, data about their clinical efficacy are scarce.

Objectives: To compare the effects of the Venturi mask and the nasal high-flow (NHF) therapy on Pa_{O_2}/FI_{O_2SET} ratio after extubation. Secondary endpoints were to assess effects on patient discomfort, adverse events, and clinical outcomes.

Methods: Randomized, controlled, open-label trial on 105 patients with a Pa_{O_2}/FI_{O_2} ratio less than or equal to 300 immediately before extubation. The Venturi mask (n = 52) or NHF (n = 53) were applied for 48 hours postextubation.

Measurements and Main Results: Pa_{O_2}/FI_{O_2SET}, patient discomfort caused by the interface and by symptoms of airways dryness (on a 10-point numerical rating scale), interface displacements, oxygen desaturations, need for ventilator support, and reintubation were assessed up to 48 hours after extubation. From the 24th hour, Pa_{O_2}/FI_{O_2SET} was higher with the NHF (287 ± 74 vs. 247 ± 81 at 24 h; $P = 0.03$). Discomfort related both to the interface and to airways dryness was better with NHF (respectively, 2.6 ± 2.2 vs. 5.1 ± 3.3 at 24 h, $P = 0.006$; 2.2 ± 1.8 vs. 3.7 ± 2.4 at 24 h, $P = 0.002$). Fewer patients had interface displacements (32% vs. 56%; $P = 0.01$), oxygen desaturations (40% vs. 75%; $P < 0.001$), required reintubation (4% vs. 21%; $P = 0.01$), or any form of ventilator support (7% vs. 35%; $P < 0.001$) in the NHF group.

Conclusions: Compared with the Venturi mask, NHF results in better oxygenation for the same set FI_{O_2} after extubation. Use of NHF is associated with better comfort, fewer desaturations and interface displacements, and a lower reintubation rate.
Clinical trial registered with www.clinicaltrials.gov (NCT 01575353).

Keywords: oxygen therapy; extubation; weaning; high-flow oxygen therapy; patient comfort

Acute respiratory failure (ARF) is the most common reason for admission in the intensive care unit (ICU), often requiring endotracheal intubation and the institution of mechanical ventilation until resolution of the underlying disease. Oxygen therapy is used to correct residual impairment in oxygenation after interruption of the ventilator support and removal of the

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At a Glance Commentary

Scientific Knowledge on the Subject: Oxygen therapy is commonly used after extubation. Nasal high-flow (NHF) therapy has been made available recently for adult patients. Comprehensive data about its clinical efficacy are scarce.

What This Study Adds to the Field: As compared with Venturi mask, the use of NHF therapy resulted in better oxygenation for the same set FI_{O_2}. In addition, discomfort related to the interface and to airways dryness improved, whereas the breathing frequency and the rate of interface displacement and of oxygen desaturation decreased. Fewer patients in the NHF group required reintubation during the study period, suggesting a potential role of this device in protecting extubation.

endotracheal tube. Several devices for oxygen delivery are available in critically ill patients, such as high-concentration reservoir mask, simple face mask, Venturi mask, and nasal cannula (1). The Venturi mask is frequently used because it allows delivery of predetermined, nominal, FI_{O_2} (1). The Venturi mask, as all the aforementioned low-flow systems, provides oxygen at flow rates that are lower than patients' inspiratory demands; thus, when the patient's inspiratory flow exceeds the gas flow rate from the mask, room air is entrained. The final concentration of oxygen truly delivered to the patient can be lower than the set FI_{O_2} (FI_{O_2SET}) and depends on the ventilatory demands of the patient (2, 3). The mask may also reduce patient comfort and it is more likely to be displaced by the patient than nasal cannula (4). Breathing dry oxygen provokes dryness of the mouth, nose, throat, and respiratory tract, which may frequently result in discomfort and pain particularly in the ICU setting (5). Clinical practice guidelines recommend humidifying the oxygen when administered at flow rates exceeding 4 L/min, because the humidification provided by the nasal mucosa becomes insufficient (6). Full humidification of inspired gas may thus improve patient comfort and facilitate the elimination of secretions.

Recently, a new device has been proposed in adult patients with ARF (7) and newborns (8): this device delivers fully humidified, high-flow oxygen (up to 60 L/min) through a nasal cannula (Optiflow; Fisher and Paykel Healthcare, Auckland, New Zealand). By delivering the gas at flow rates that exceed the patient's peak inspiratory flow rate, this high-flow system provides a constant FI_{O_2}. With this device, the final concentration of oxygen truly delivered to the patient is equivalent to the FI_{O_2SET} (2). In addition, a flow-dependent effect of continuous positive airway pressure has been documented in healthy subjects (9) and in patients (10, 11). Last, the high gas flow may generate an upper airways deadspace washout effect and may create an oxygen reservoir within the upper airways (12). Through these mechanisms, the nasal high-flow (NHF) device has the potential to improve oxygenation as compared with conventional low-flow systems for oxygen therapy, such as the Venturi mask (7). We performed a randomized, controlled trial comparing NHF with the Venturi mask in critically ill patients requiring oxygen therapy after extubation, with the hypothesis that NHF could improve oxygenation. We also assessed the effects of the two devices on patient comfort, adverse events, and clinical outcome. Some of the results of this study have been previously reported in the form of an abstract (13).

Methods

Additional methods are available in the online supplement. The study was conducted in two Italian ICUs (Rome and Novara). Institutional review committees approved the study, and written informed consent was obtained from patients or surrogates. Patients mechanically ventilated for more than 24 hours were screened for enrollment. Patients were eligible for inclusion if they successfully passed a spontaneous breathing trial (14), and had a Pa_{O_2}/FI_{O_2} less than or equal to 300 at the end of the spontaneous breathing trial. Exclusion criteria were age less than 18, pregnancy, tracheostomy, do-not-intubate status, and planned use of noninvasive ventilation (NIV) after extubation. Planned postextubation NIV was based on the following *a priori* criteria: more than three consecutive failures of the spontaneous breathing trial (15), and a Pa_{CO_2} greater than 45 mm Hg with a respiratory rate greater than 25 per minute just before the spontaneous breathing trial (16).

At the time of extubation, all patients had a normal mental status and none of them had delirium. Just after extubation, patients were randomized to receive oxygen through the Venturi mask (control group) or the NHF (intervention group). Randomization was done in a masked fashion, using opaque envelopes, with a unique computer-generated, random number sequence for both sites. In both groups, FI_{O_2SET} was adjusted to obtain an Sa_{O_2} between 92% and 98% (88–95% in patients with compensated hypercapnia). With NHF, the gas flow rate was 50 L/min. The Venturi mask or the NHF were applied for 48 hours or up to ICU discharge.

Arterial blood gases, Sa_{O_2}, FI_{O_2SET}, respiratory rate, mean arterial pressure, heart rate, and patient discomfort were recorded at 1, 3, 6, 12, 24, 36, and 48 hours. Patient discomfort was assessed by asking patients to rate discomfort related both to the interface (face mask or nasal cannula) and to the symptoms of airways dryness (mouth, throat, and nose dryness; difficulty in swallowing; and throat pain) on an ICU-adapted, large-print, numerical rating scale, from 0 (no discomfort) to 10 (maximum discomfort) (*see* Figure E1 in the online supplement) (17, 18).

Adverse events included (*1*) displacement of the oxygenation device; (*2*) oxygen desaturation ($Sa_{O_2} < 92\%$ or $< 88\%$ in patients with compensated hypercapnia); and (*3*) postextubation ARF requiring the institution of NIV or endotracheal intubation. Decisions to apply NIV and to perform endotracheal intubation were based on *a priori* criteria (16, 19, 20).

Primary endpoint was oxygenation (i.e., the Pa_{O_2}/FI_{O_2SET} at 24 h). Secondary endpoints were patient discomfort, episodes of device displacement, episodes of oxygen desaturation, occurrence of postextubation ARF requiring any form of ventilator support, and reintubation.

Statistics

The Venturi mask is an oxygenation device delivering low gas flow, such as the nasal cannula and the simple mask. For the sample size calculation, we searched for studies comparing the effects of any low-flow systems and NHF on oxygenation and found three publications (7, 10, 21). Lacking preliminary data of comparison between

the Venturi mask and the NHF, we decided to proceed conservatively and we based our power analysis on the most unfavorable case (i.e., the study by Corley and coworkers [10]) reporting the lowest improvement in oxygenation with NHF (31 mm Hg), coupled with the highest estimate of variance (SD, 56 mm Hg) (10). We therefore hypothesized that NHF would have improved the Pa_{O_2}/FI_{O_2SET} by at least 31 mm Hg at 24 hours, as compared with the Venturi mask. With a type 1 error of 0.05 and a power of 80% we calculated a sample size of 104 patients (52 patients in each arm).

Because masking of patients and personnel to treatment was not possible, we tried to minimize a biased ascertainment of outcome as follows: the database was monitored by third parties with no direct involvement in the study procedures and no interest in outcome; and the data analysis was performed exactly according to the statistical analysis plan decided before the study started. Data were analyzed with an intention-to-treat approach. Categorical variables were reported as percentages and continuous variables as mean ± SD. Comparisons of continuous variables between groups were performed using analysis of variance. Comparisons between categorical variables were performed using the chi-square test. *P* less than 0.05 was considered statistically significant. In the present study, only the primary endpoint (Pa_{O_2}/FI_{O_2SET} at 24 h) was rigorously tested at a 5% type 1 error level: all other tests on secondary endpoints were merely exploratory in nature, and no multiple inference corrections were applied.

Results

Between November 2010 and April 2011, 105 patients were enrolled in the study, 52 in the control group and 53 in the intervention group (Figure 1). Patient characteristics at inclusion were similar between groups (Table 1). Mean age was 64 ± 17 years, and Simplified Acute Physiologic Score II was 43 ± 15. The main causes of ARF requiring endotracheal intubation were pneumonia (46%) and trauma (22%), and the mean duration of mechanical ventilation before inclusion was 4.9 ± 3.9 days. At enrollment, the mean Pa_{O_2} was 91.6 ± 21.9 mm Hg, Pa_{O_2}/FI_{O_2SET} was 240.6 ± 46.7, Sa_{O_2} was 97.0 ± 2.3%, Pa_{CO_2} was 35.3 ± 7.3 mm Hg, and respiratory rate was 23 ± 5 breaths/min.

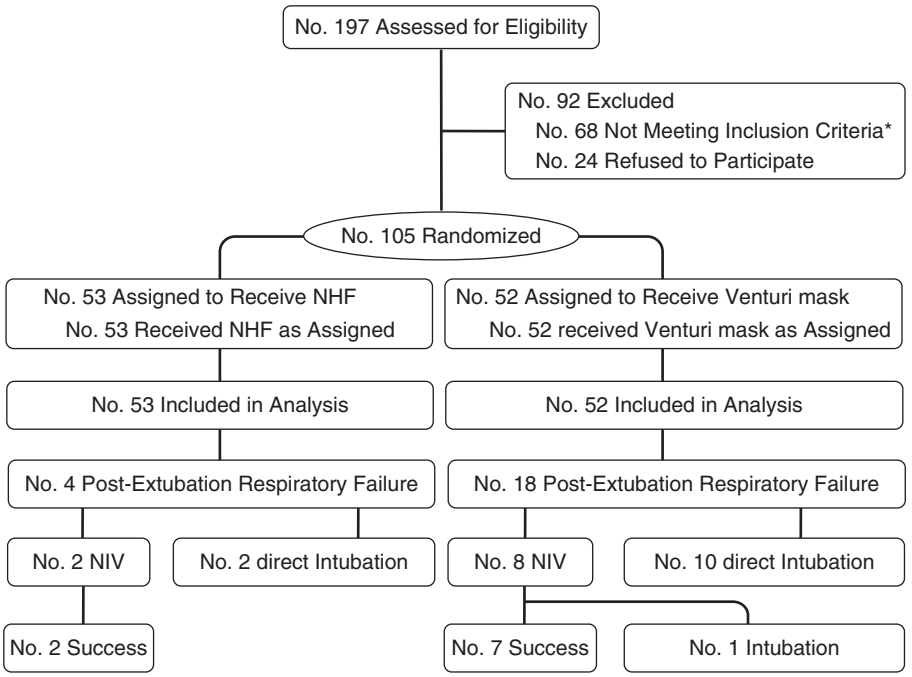

Figure 1. Trial profile. *10 patients (15%) failed the spontaneous breathing trial, 30 patients (44%) did not meet the criterion for oxygen therapy (i.e., $Pa_{O_2}/FI_{O_2} \leq 300$ at the end of the spontaneous breathing trial preceding extubation), and 28 patients (41%) received prophylactic noninvasive ventilation immediately after extubation. NHF = nasal high-flow oxygen therapy; NIV = noninvasive ventilation.

Respiratory and Hemodynamic Parameters

The Pa_{O_2}/FI_{O_2SET} ratio was significantly higher with NHF at 24 hours (287.2 ± 74.3 mm Hg vs. 247.4 ± 80.6 mm Hg; $P = 0.03$), at 36 hours (310.8 ± 87.7 mm Hg vs. 233.2 ± 75.8 mm Hg; $P = 0.0003$), and at 48 hours (313.3 ± 83.8 mm Hg vs. 250.2 ± 110.1 mm Hg; $P = 0.01$) (Figure 2). Pa_{O_2} values were higher with NHF at 36 hours only (97.5 ± 29.2 mm Hg vs. 85.4 ± 16.3 mm Hg; $P = 0.04$), whereas FI_{O_2SET} was significantly lower with the NHF at all time steps (35.1 ± 8% vs. 39.3 ± 9.1% on average in the 48-h study period; $P = 0.014$). Sa_{O_2} was significantly greater with the NHF system than with the Venturi mask at all time steps (Figure 2). Pa_{CO_2} was always lower with the NHF, and at 3 hours the difference was statistically significant (32.3 ± 7.1 mm Hg vs. 36.2 ± 11 mm Hg; $P = 0.04$) (Figure 2). Respiratory rate was always significantly lower with the NHF system, with a mean difference of 4 ± 1 breaths/min (Figure 2). Heart rate and mean arterial blood pressure were always similar between groups.

Patient Discomfort

Results are depicted in Figure 3. Discomfort related to the interface was significantly lower with the NHF system from the 12th hour. Similarly, discomfort related to the symptoms of airways dryness was significantly lower with NHF from the 24th hour. In particular, as compared with the Venturi mask, use of the NHF was associated with a lower discomfort related to mouth dryness (3.6 ± 2.5 vs. 5 ± 3.1 on average during the 48-h study period; $P = 0.016$), throat dryness (2.7 ± 2.4 vs. 4.5 ± 3.3; $P = 0.002$), difficulty to swallow (2.5 ± 2.6 vs. 4.1 ± 3.4; $P = 0.007$), and throat pain (1.7 ± 2.1 vs. 3.1 ± 3.4; $P = 0.008$).

Adverse Events and Clinical Outcomes

There were a total of 109 episodes of interface displacement: 20 episodes in the NHF group (0.4 episodes per patient) and 89 in the Venturi mask group (1.7 episodes per patient) ($P < 0.001$). Fewer patients displaced the interface with the NHF than with the Venturi mask (17 [32.1%] vs. 29 [55.8%] patients, respectively; $P = 0.01$).

There were 218 episodes of oxygen desaturation detected on the bedside clinical

Table 1. Characteristics of Patients at Inclusion

	Control Group (*n* = 52)	NHF (*n* = 53)	*P* Value
Age, yr	64 ± 17	65 ± 18	0.9
Male sex, n (%)	35 (67.3)	33 (62.3)	0.73
SAPS II	44 ± 16	43 ± 14	0.73
Type of admission			0.5
Medical, n (%)	31 (60)	35 (66)	
Surgical-trauma, n (%)	21 (40)	18 (34)	
Cause of acute respiratory failure			0.78
Pneumonia, n (%)	24 (46.2)	24 (45.3)	
Multiple trauma, n (%)	12 (23.1)	11 (20.8)	
Atelectasis, n (%)	5 (9.6)	4 (7.5)	
Shock, n (%)	3 (5.8)	5 (9.4)	
Cardiogenic pulmonary edema, n (%)	3 (5.8)	3 (5.7)	
Cardiac arrest, n (%)	2 (3.8)	3 (5.7)	
Other, n (%)*	3 (5.8)	3 (5.7)	
Length of mechanical ventilation before inclusion, d	5.2 ± 3.7	4.6 ± 4.1	0.43
Length of ICU stay before inclusion	5.6 ± 4.4	5.2 ± 4.4	0.67
Pa_{O_2}, mm Hg	93.4 ± 24.2	89.9 ± 19.5	0.41
Pa_{CO_2}, mm Hg	36 ± 7.1	34.7 ± 7.6	0.36
Sa_{O_2}, %	97.2 ± 2.6	96.9 ± 2.0	0.71
FI_{O_2}, %	39 ± 7	38 ± 7	0.47
Pa_{O_2}/FI_{O_2}, mm Hg	241.7 ± 51.1	239.4 ± 42.4	0.8
Respiratory rate, breaths/min	23 ± 6	23 ± 5	0.73
Heart rate, beats/min	91 ± 15	92 ± 19	0.84
Mean arterial pressure, mm Hg	94 ± 15	94 ± 12	0.88

Definition of abbreviations: ICU = intensive care unit; NHF = nasal high-flow oxygen therapy; SAPS II = Simplified Acute Physiologic Score II.
*Other causes of acute respiratory failure were hemoptysis (one patient), diabetic ketoacidosis (one patient), diabetic coma (two patients), and epileptic seizures (two patients).

monitor: 40 episodes with the NHF (0.8 episodes per patient) and 178 with the Venturi mask (3.4 episodes per patient; $P < 0.001$). Fewer patients in the NHF group had episodes of oxygen desaturation, detected electronically (21 [39.6%] vs. 39 [75%] patients; $P < 0.001$) and by nurses (10 [18.9%] vs. 27 [51.9%] patients; $P < 0.001$).

During the 48-hour study period, 22 patients suffered from postextubation ARF requiring any form of ventilator support: 4 patients (7.5%) in the intervention group and 18 patients (34.6%) in the control group ($P < 0.001$). Fewer patients received NIV ($P = 0.04$) and required endotracheal intubation ($P < 0.01$) with the NHF than with the Venturi mask (Table 2). Nine additional patients were reintubated after the 48-hour study period during their ICU stay (four patients [7.5%] vs. five patients [9.6%] in the NHF group and in the Venturi mask group, respectively; $P = 0.71$). A *post hoc* analysis showed that weaning was simple in 63 patients (58% vs. 62% of patients in the NHF group and in the Venturi mask group, respectively; $P = 0.75$), difficult in 21 patients (17% vs. 23%; $P = 0.43$), and prolonged in 21 patients (25% vs. 15%; $P = 0.24$). Length of stay in the ICU (11.7 ± 10.2 vs. 10.4 ± 8.5 d with the NHF and the Venturi mask, respectively; $P = 0.44$) and mortality at ICU discharge (11.3% vs. 9.6%; $P = 0.77$) were not different between groups. Mortality in the ICU was greater in patients who were reintubated than in patients who were

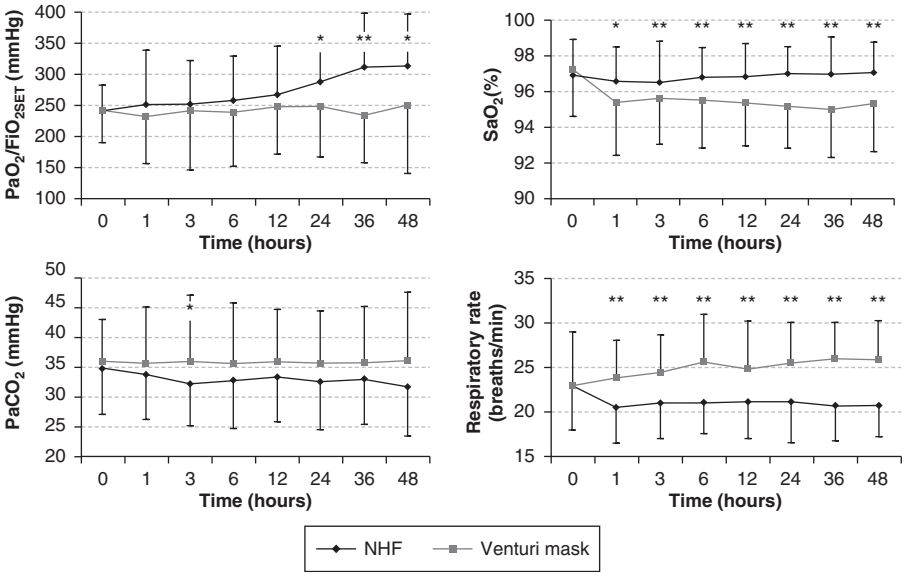

Figure 2. The 48-hour trends of the Pa_{O_2}/FI_{O_2SET} (*upper left*), the Sa_{O_2} (*upper right*), the Pa_{CO_2} (*lower left*), and the respiratory rate (*lower right*) with the nasal high-flow oxygen therapy (NHF) and the Venturi mask. Values at time 0 were recorded at the end of the successful breathing trial, just before extubation. *$P < 0.05$; **$P \leq 0.01$.

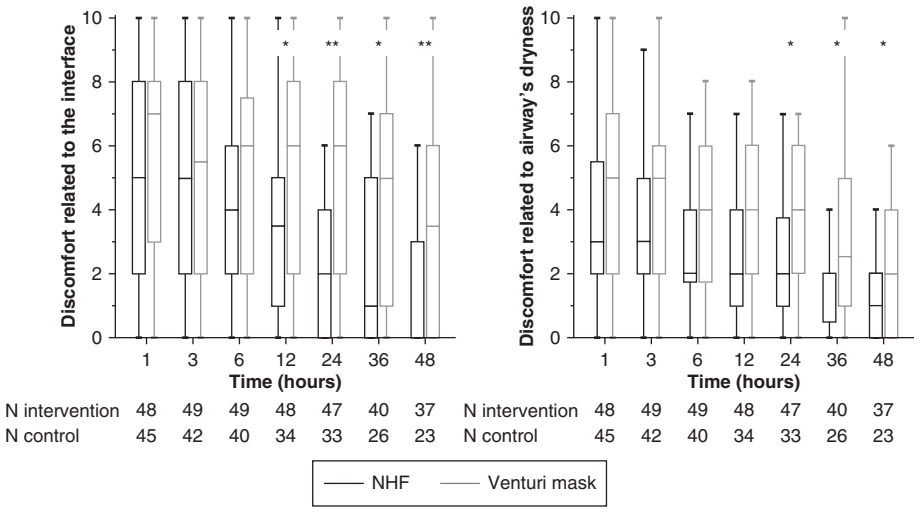

Figure 3. Box and whisker plots of patient discomfort related to the interface (*left*) and related to symptoms of airways dryness (*right*) with the nasal high-flow (NHF) oxygen therapy and the Venturi mask at the 48-hour study steps. Medians are expressed as *horizontal bars* inside the *boxes*, 25th–75th percentiles as the bottom and the top of the *boxes*, and maximal-minimal values as *whiskers*. *$P < 0.05$; **$P \leq 0.01$.

successfully weaned off the ventilator (31.8% vs. 4.8%; $P = 0.001$).

Discussion

The main results of the present study can be summarized as follows: (*1*) as compared with the Venturi mask, use of the NHF after extubation results in better oxygenation for the same set FI_{O_2}; (*2*) the NHF decreases respiratory rate and improves patient discomfort both related to the interface and to symptoms of airways dryness; (*3*) use of the NHF is associated with fewer episodes of interface displacement and of oxygen desaturation; and (*4*) use of the NHF in the postextubation period is associated with less need for NIV and endotracheal intubations than the Venturi mask. It must be noted that our findings concerning secondary endpoints, such as weaning outcome, must be considered exploratory in nature and not demonstrative of any formal hypothesis.

Effect of NHF on Oxygenation

With a high-flow system, the ventilatory demand of the patient is completely met by the gas flow delivered by the device. In contrast, the oxygenation device is classified as a low-flow system when it fails to meet the ventilator demand of the patient. The flow rate delivered by the system should not be confused with the oxygen concentration. Indeed, a high-flow system, such as the NHF, can deliver low FI_{O_2}, whereas a low-flow system, such as the Venturi mask, can deliver FI_{O_2} as high as 60% (3).

In the present study, we found that, as compared with the Venturi mask, NHF results in better oxygenation for the same set FI_{O_2}. Several mechanisms could explain this effect. First, by delivering the gas at flow rates that exceed the patient's peak inspiratory flow rate, this device provides a constant FI_{O_2}. As a result, the final concentration of oxygen truly delivered to the patient is equivalent to the FI_{O_2SET} (2). Several authors have shown that the delivered FI_{O_2} is greater with high-flow oxygenation devices than with the standard systems supplying low gas flow rates (2, 22). With these latter devices, the delivered FI_{O_2} can decrease considerably when the patient's inspiratory flow is high, as it is often the case in critically ill patients (1, 2, 23). It has been shown that patients with tachypnea (i.e., a respiratory rate >30 breaths/min) often have an inspiratory flow rate above the flow rate delivered by the Venturi system, which in turn can induce a significant entrainment of room air and the dilution of the inspired oxygen. Second, the high gas flow can washout the upper airways deadspace and may create an oxygen reservoir within the upper airways (12). Finally, the high gas flow generates a positive airway pressure of 2–5 cm H_2O, which is proportional to gas flow and may recruit the atelectatic lung (10, 24). Previous studies reported that lung derecruitment may occur during weaning from mechanical ventilation (25) and atelectasis may persist up to 24–48 hours after extubation following anesthesia and paralysis (26). We reasoned that, through the aforementioned mechanisms, the NHF could reverse postextubation atelectasis and improve oxygenation.

Several studies have suggested that NHF may improve oxygenation compared with low-oxygen flow devices (7, 10, 12, 21). In line with these studies, we also found that oxygenation, for the same set FI_{O_2}, was improved by the NHF. In our study, improvement in the Pa_{O_2}/FI_{O_2SET} with the NHF did not manifest immediately but was delayed for 24 hours. This could be explained by the fact that lung recruitment is a time-dependent phenomenon, all the most when the amount of applied pressure

Table 2. Need for Ventilatory Support during the 48-Hour Study Period

	Control Group (*n = 52*)	NHF (*n = 53*)	*P* Value
Noninvasive ventilation, n (%)	8 (15.4)	2 (3.8)	0.042
Endotracheal intubation, n (%)	11 (21.2)	2 (3.8)	0.005
Cause of endotracheal intubation			
Hypercapnia with respiratory acidosis, n (%)	0	0	N/A
Changes in mental status, n (%)	1 (1.9)	1 (1.9)	0.989
Oxygen desaturation or hypoxia, n (%)	6 (11.5)	1 (1.9)	0.047
Unbearable dyspnea with respiratory muscle failure, n (%)	4 (7.7)	1 (1.9)	0.162
Persistent hypotension, n (%)	2 (3.8)	0	0.149
Inability to clear secretions, n (%)	6 (11.5)	1 (1.9)	0.047

Definition of abbreviation: NHF = nasal high-flow oxygen therapy.

is low. Because the NHF can generate a low level of positive airway pressure (10, 24), the time needed for recruiting the atelectatic lung could have been longer.

Effect of NHF on Other Respiratory Parameters

The contemporary decrease in the respiratory rate and in the Pa_{CO_2} suggests that deadspace was reduced with the NHF. There are two main mechanisms through which NHF may decrease deadspace: increase in tidal volume and improvement in inspiratory air-flow dynamics (27). Alternatively, NHF could have washed out the nasopharyngeal deadspace volume, thus producing a sort of unidirectional breathing that is known to reduce inspired deadspace volume (28). As reported by others (7, 10, 21), we also found that respiratory rate was lower with the NHF. It has been shown that normal individuals change their breathing pattern, which becomes slower and deeper with the NHF (27). The increase in tidal volume decreases the anatomic deadspace and improves breathing efficiency, thus explaining the reduction in Pa_{CO_2} with NHF (27). The slower and deeper breathing can also decrease the work of breathing (29) and can relieve dyspnea through a neural pathway including the activation of central and reflex mechanisms (30). The lower respiratory rate observed with the NHF can be explained by a decreased patient inspiratory effort (31), although this remains a speculation because we did not measure this parameter.

Effect of NHF on Patient Comfort

In the present study, the NHF reduced patient discomfort related both to the interface and to the symptoms of airways dryness. Some clinical studies have suggested that nasal cannulae are preferred and better tolerated by patients than face mask. In patients receiving nocturnal low-flow oxygen at home, Costello and coworkers (4) reported a better tolerance with nasal cannula than with the face mask. In addition, most patients preferred the nasal interface, whereas the Venturi mask was dislodged more frequently. Other studies in critically ill patients also suggested that the nasal cannula improves comfort as compared with the face mask (7, 10, 32–34). We found that discomfort related to the interface was lower with the NHF, particularly after the first 12 hours. In addition, the NHF system decreased the discomfort related to symptoms of airways dryness as compared with the Venturi mask. A better gas humidification obtained with the NHF may explain this finding. Indeed, several investigators have reported that improving the humidification of the inspired gas ameliorates patient comfort (5, 35–37).

Effect of NHF on Adverse Events and Weaning Outcome

The NHF reduced the incidence of adverse events, such as interface displacement and oxygen desaturation. The improved comfort with the NHF may explain our finding that the use of this device was associated with less displacement of the interface. In turn, we speculate that the better tolerance and the fewer interface dislodgements may have reduced the episodes of oxygen desaturation with the NHF, as opposed to the Venturi mask. This finding is in line with the results of a previous study showing that the use of nasal cannulae was associated with fewer oxygen desaturations as compared with the face mask in patients undergoing high-flow oxygen therapy (32).

Noteworthy, we found that the use of the NHF in the postextubation period was associated with less need for NIV and fewer endotracheal intubations than the Venturi mask. The improvement in oxygenation, comfort, and compliance with the therapy together with the improved patient ability to clear secretions may explain this finding, although we cannot exclude that other factors, including a decreased patient inspiratory effort and a better lung recruitment, may have played a role. Our study was not aimed at demonstrating the superiority of the NHF system over the Venturi mask in the weaning outcome and it was not powered for that purpose. This finding must therefore be considered as hypothesis-generating and not as a definitive conclusion.

Study Limitations

Our study has limitations. First, masking of patients and personnel to treatment was not performed because it was obviously not possible. However, the database has been controlled by third parties with no direct involvement in the study procedures and no interest in outcome. In addition, the data analysis has been carefully performed precisely according to the statistical analysis plan decided before the study started. Finally, we used *a priori*, objective, and uniform criteria for assessing secondary outcomes, such as the application of NIV and reintubation. Second, we did not measure the true FI_{O_2} delivered to patients and we cannot exclude that FI_{O_2} was indeed greater with the NHF than with the Venturi mask. In that case, the improvement that we found in the Pa_{O_2}/FI_{O_2SET} and in the Sa_{O_2} with the NHF would simply reflect a better oxygen delivery more than a true improvement in oxygenation (2, 22). The improvement in several other parameters suggests that our patients did not worsen, and even improved, with the NHF. The NHF prevented, for instance, oxygen desaturation better than the Venturi mask. In addition, the measurement of the true FI_{O_2} delivered to the patient would have required invasive maneuvers, such the insertion of a nasopharyngeal catheter (22). These maneuvers could have reduced patient comfort, thus affecting our results concerning this parameter. Third, assessment of patient discomfort was subjective. However, the numerical scale we used is well suited for critically ill patients (38, 39) and has better validity and reliability for measuring acute pain than a visual analog scale or verbal scale (17). In addition, none of the enrolled patients had delirium. Lastly, all patients had an arterial blood gas collected at the end of the successful spontaneous breathing trial, immediately before extubation. We acknowledge that measurement of arterial blood gases is not common practice in this context but we believed that, for the research purpose, it was important to make sure that oxygenation impairment was similar in the two groups at baseline.

Conclusions

In conclusion, as compared with the Venturi mask, the use of the NHF system in the postextubation period results in better oxygenation for the same set FI_{O_2}. In addition, the NHF decreases Pa_{CO_2} and the respiratory rate, while improving patient comfort and reducing episodes of interface dislodgement and oxygen desaturation. Finally, our data suggest a potential role of NHF in protecting extubation, a hypothesis that deserves a further, adequately powered, randomized controlled trial. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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