Humidified High Flow Nasal Oxygen During Respiratory Failure in the Emergency Department: Feasibility and Efficacy

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OBJECTIVE: Heated and humidified high flow nasal cannula oxygen therapy (HFNC) represents a new alternative to conventional oxygen therapy that has not been evaluated in the emergency department (ED). We aimed to study its feasibility and efficacy in patients exhibiting acute respiratory failure presenting to the ED. METHODS: Prospective, observational study in a university hospital's ED. Patients with acute respiratory failure requiring > 9 L/min oxygen or with ongoing clinical signs of respiratory distress despite oxygen therapy were included. The device of oxygen administration was then switched from non-rebreathing mask to HFNC. Dyspnea, rated by the Borg scale and a visual analog scale, respiratory rate, and S_{pO_2} were collected before and 15, 30, and 60 min after beginning HFNC. Feasibility was assessed through caregivers' acceptance of the device in terms of practicality and perceived effect on the subjects, evaluated by questionnaire. RESULTS: Seventeen subjects, median age 64 y (46–84.7 y), were studied. Pneumonia was the most common reason for oxygen therapy ($n = 9$). HFNC was associated with a significant decrease in both dyspnea scores: Borg scale from 6 (5–7) to 3 (2–4) ($P < .001$), and visual analog scale from 7 (5–8) to 3 (1–5) ($P < .01$). Respiratory rate decreased from 28 breaths/min (25–32 breaths/min) to 25 breaths/min (21–28 breaths/min) ($P < .001$), and S_{pO_2} increased from 90% (88.5–94%) to 97% (92.5–100%) ($P < .001$). Fewer subjects exhibited clinical signs of respiratory distress (10/17 vs 3/17, $P = .03$). HFNC was well tolerated and no adverse event was noted. Altogether, 76% of healthcare givers declared preferring HFNC, as compared to conventional oxygen therapy. CONCLUSIONS: HFNC is possible in the ED, and it alleviated dyspnea and improved respiratory parameters in subjects with acute hypoxemic respiratory failure. *Key words: acute lung injury; acute respiratory distress syndrome; dyspnea; oxygen inhalation therapy; mouth dryness; intensive care equipment and supplies.* [Respir Care 2012;57(11):1873–1878. © 2012 Daedalus Enterprises]

Introduction

Dyspnea is one of the most common complaints in patients presenting to the emergency department (ED). Oxygen therapy is then one of the first treatments provided, according to current guideline.[1,2] It can be delivered—depending on the severity of the patient's respiratory distress—during either unassisted (via nasal cannulas or face masks) or assisted breathing with noninvasive or invasive mechanical ventilation.[3] In patients who do not require immediate mechanical ventilation, important drawbacks are associated with conventional oxygen therapy. These include the limited amount of oxygen supplied (15 L/min is usually the maximum flow delivered via a face mask),

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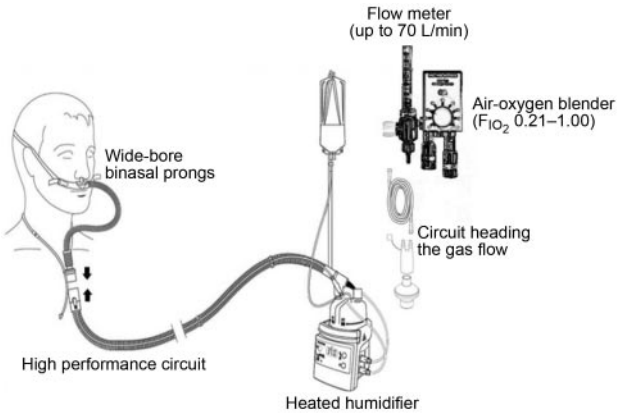

Fig. 1. Scheme of the high flow nasal cannula Optiflow device. It consists of an air-oxygen blender with adjustable F_{IO_2} (0.21–1.0) that delivers a modifiable gas flow (up to 60 L/min) to a heated chamber where the gas is heated and humidified. The gas mixture is then routed through a high performance circuit to be delivered at 37°C containing 44 mg H_2O/L to the patient via short, wide bore binasal prongs. (Courtesy of Fisher & Paykel.)

the considerable imprecision regarding the exact delivered F_{IO_2},[4] and the poor tolerance of oxygen in some patients because of insufficient heating and humidifying.[5-7]

Recently, an alternative to conventional oxygen therapy has received growing attention: heated, humidified high flow nasal cannula oxygen (HFNC) is a technique that can deliver up to 100% heated and humidified oxygen at a maximum flow of 60 L/min of gas via nasal prongs or cannula under body temperature (37°C) and pressure with saturated water conditions (100% of relative humidity) (Fig. 1). Most of the available data with this technique have been published in the neonatal field, where it is increasingly used.[8] Several devices have been tested so far,[9] but evaluation of HFNC in adults remains limited.[7] Beneficial effects on respiratory parameters have been recently reported in ICU patients with acute respiratory failure[10-14] and during heart failure.[15] In addition, low levels of positive pressure have been measured in patients recovering from cardiac surgery with HFNC,[16] as well as in healthy volunteers.[17] There are no data concerning the use of such a device in the ED, despite dyspnea and respiratory failure being common features of patients and specificities in the management in response to the environment. Hence, the aim of this study was to determine the feasibility and the effect of HFNC in patients with acute respiratory failure presenting to the ED.

QUICK LOOK

Current knowledge

High flow, heated, humidified oxygen delivered via a nasal cannula has become a common therapy for treating hypoxemia. This therapy has not been commonly used in the emergency department.

What this paper contributes to our knowledge

The use of high flow, heated, and humidified oxygen by nasal cannula was associated with a lower respiratory rate, higher oxygen saturation, and improved comfort scales, compared to conventional oxygen therapy in a group of patients with hypoxemia in the emergency department.

Methods

Study Design

A prospective, observational study was conducted in the ED of a university hospital. The ethics committee of the French Society of Intensive Care Medicine approved the study and waived informed consent, since the procedures were all part of routine care. Subjects were informed of the study, its design and purpose, and all healthcare givers (nurses and physicians) were educated to this new system with theoretical information and demonstration provided by the manufacturer before the beginning of the study.

Population

Between January and April 2009, all consecutive adult patients who presented in our ED and who received conventional oxygen therapy with a non-rebreathing high F_{IO_2} face mask with reservoir (Hudson RCI, Teleflex Medical, High Wycombe, United Kingdom) were screened for eligibility. They were included if they remained dyspneic despite aggressive conventional therapy (including a minimum of 9 L/min oxygen via the face mask, and a maximum of 15 L/min, although it is possible to deliver greater values, but without knowing precisely how much). They were excluded if they required immediate invasive or noninvasive mechanical ventilation or if they had hypercapnic respiratory failure.

Sequence and Data Collection

General and demographic data were collected. While HFNC was prepared, all variables were measured under the face mask. HFNC was delivered via a dedicated high flow delivery system (Optiflow, Fisher & Paykel, Auckland, New Zealand). HFNC settings were left to the attending physician's discretion, but internal discussion with the medical team recommended for most cases an $F_{IO_2} \geq 60\%$ with initial flow of 40 L/min. These settings could obviously be adapted depending on the subject's severity

and tolerance of HFNC. Its efficacy was assessed on its capacity: to alleviate dyspnea, using the Borg scale[18] and a visual analog scale (in those subjects whose neurological status allowed them to complete the evaluation); to decrease respiratory rate); and to increase S_{pO_2}. All these variables were collected before HFNC, while the subject was breathing through the high-F_{IO_2} face mask, and 15, 30, and 60 min after using HFNC. To keep this study the least invasive, we decided not to systematically sample arterial blood for blood gas assessment. Arterial blood gases were performed at the attending physician's discretion, which explains their being performed in only a subset of subjects, before and after HFNC therapy. At the end of the first hour's use of HFNC, subjects were asked to rate, by means of a simple questionnaire, their appreciation of the device in terms of overall comfort and noise, in comparison with the face mask (more, less, or similar to conventional oxygen therapy). To ensure a more objective assessment, ambient noise, HFNC and conventional therapy generated noise were measured with a sound level meter (SdB02, Calright Instruments, San Diego, California). Measurements were performed in the room, 1 m away from the device. Finally, healthcare givers were asked their opinion of HFNC preparation and setup and its efficacy, with the same rating as subjects: more, less, or similar. The feasibility was determined according to these ratings.

Statistical Analysis

Statistical analysis was performed using statistics software (Prism 4, GraphPad Software, San Diego, California). Results are expressed as median and interquartile range (1QR). The Friedman test was used to compare paired repeated measurements. The Wilcoxon test was used to compare paired measurements. The chi-square test was used for categorical variables. A P value $< .05$ was considered significant.

Results

During the study period, 386 patients admitted to the ED experienced dyspnea, among whom 17 met the aforementioned inclusion criteria for this study (see subject flow chart, Fig. 2). The median age was 64 years (46–84.7 y), and the sex ratio was 9/8 (female/male). The median Simplified Acute Physiology Score II was 33 (18.5–39.5). The main causes of respiratory failure were pneumonia, ($n = 9$), cardiogenic pulmonary edema ($n = 4$), pneumothorax ($n = 1$), acute asthma ($n = 1$), pleural effusion ($n = 1$), and septic shock ($n = 1$). Eight subjects' initial neurological status prevented them from fulfilling the Borg and visual analog scale evaluation, which is available for the 9 remaining subjects. The median oxygen flow through the face mask prior to HFNC was 15 L/min (10.5–15 L/min). The median S_{pO_2} was 90% (88.5–94%), and the median respiratory rate was 28 breaths/min (25–32 breaths/min). HFNC was instituted 94.5 min (53.5–139.5 min) after subjects crossed the emergency room door, with a median flow of 40 L/min (30–40 L/min) and a median F_{IO_2} of 1.0 (0.70–0.10). Compared to the variables at hour zero, while receiving oxygen therapy through face mask, HFNC was associated with a significant decrease in dyspnea intensity in both the Borg score and the visual analog scale as early as 15 min (Table). After 15 min, respiratory rate decreased significantly ($P < .05$) and S_{pO_2} increased significantly ($P < .01$) (see Table). These beneficial effects were maintained throughout the study period (see Table). Fewer subjects exhibited clinical signs of respiratory distress after one hour of HFNC (10/17 vs 3/17, $P = .03$).

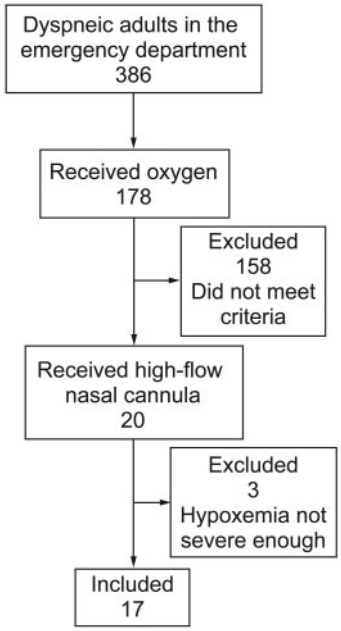

Fig. 2. Subject flow chart.

Some subjects had arterial blood gases performed immediately upon arrival (before oxygen therapy was started), and the attending physician did not repeat them during conventional oxygen therapy. Similarly, some subjects improved so dramatically under HFNC that the attending physician did not require additional arterial blood gases. In the remaining subjects ($n = 6$) in whom arterial blood gases were performed before and during HFNC, P_{aO_2} increased significantly, from 61 mm Hg (56–74 mm Hg) to 129 mm Hg (96–194 mm Hg) ($P = .04$), with no significant changes in pH (7.40 [7.35–7.44] vs 7.42 [7.35–7.44], $P = .80$) or P_{aCO_2} (40 mm Hg [34.5–47 mm Hg] vs 40 [35.5–46] mm Hg, $P = .90$).

Nine subjects were hospitalized in the ICU and 8 in the ED's short course hospitalization unit. HFNC was contin-

Table. Changes in Dyspnea and Respiratory Parameters Comparing Conventional Oxygen Therapy to High Flow Nasal Cannula

	H0	H + 15 min	H + 30 min	H + 60 min
Borg scale (n = 9)	6 (5–7)	4 (3–4)*	4 (2–4)†	3 (2–4)†
Visual analog scale (n = 9)	7 (5–8)	5 (2–6)*	4 (2–6)†	3 (1–5)‡
Respiratory rate, breaths/min (n = 17)	28 (25–32)	25 (23–30)*	25 (21–30)‡	25 (21–28)†
S_{pO_2}, % (n = 17)	90 (88.5–94)	96 (90–99)‡	95 (90–100)†	97 (92.5–100)†

Values are median (1QR).
* $P < .05$.
† $P < .001$.
‡ $P < .01$.
H0 = time just before switching from conventional oxygen therapy to high flow nasal cannula;

ued for all subjects admitted to the ICU. Seven were successfully weaned from HFNC after a median time of use of 13.5 h (4–34.5 h) and fully recovered. Two required invasive mechanical ventilation, and one subject ultimately died. In the ED's hospitalization unit, 5 subjects for whom do-not-resuscitate orders had been given died; the remaining 4 subjects were ultimately discharged.

Nine subjects were able to give their opinion of the device. All but one stated greater comfort with HFNC than with the face mask. Two of them declared having been disturbed by the noise. Objective sound level measurement indicated that HFNC generated 55 dB, oxygen via the face mask 50 dB, and ambient noise in the ED oscillated between 60–70 dB.

All caregivers (n = 17) judged HFNC more efficient than conventional oxygen therapy through the face mask. There were 82% who estimated that subjects were more comfortable with this device. In terms of set-up and management, 65% found no difference between HFNC and conventional oxygen therapy, while 24% found HFNC less difficult and 12% more difficult to set up and manage. Altogether, 76% of healthcare givers declared preferring HFNC, as compared to conventional oxygen therapy.

Discussion

Our study shows for the first time the beneficial effects of HFNC to alleviate dyspnea and improve respiratory status of patients presenting to the ED with respiratory failure. These beneficial effects were seen in both objective parameters (respiratory rate and S_{pO_2}) and subjective ones (Borg score and visual analog scale). Our results highlight the fact that this technique is feasible and effective in the ED and that it could be used as the first line therapy in the most severe patients. Whether or not this technique can reduce the number of patients requiring ICU admission and mechanical ventilation remains to be further addressed.

Several factors can account for the beneficial effects of HFNC observed in our study. High gas flow enhances washout of the nasopharyngeal dead space[19] and improves oxygenation through greater alveolar oxygen content.[20] In addition, high oxygen flow reduces ambient air entrainment by providing a better matching between patient's inspiratory demand and oxygen flow, thus considerably reducing oxygen dilution. The increase in patient oxygenation may blunt the respiratory drive induced by hypoxemia and decrease the sensation of dyspnea. A decrease in inspiratory nasopharyngeal resistance may also result from the use of high oxygen flow, enabling a decrease in the work of breathing.[20] The use of high flows also generate a certain level of positive pressure,[16,17,21] contributing to the pulmonary distending pressure and recruitment. Finally, by providing heated and humidified oxygen, HFNC reduces the metabolic cost of gas conditioning and improves lung and airway mechanics through adequate inspiratory gas flow rheology.

Of note, we were able to start HFNC very shortly after the patients' admission to the ED. Whether a prompt alleviation of respiratory distress and a faster correction of hypoxemia can alter the course of these patients and lead to less ICU admission and potential intubation, in comparison with conventional oxygen therapy, remains to be proven in a randomized controlled trial. Nonetheless, our results constitute a prerequisite for this trial to be conducted.

One noticeable aspect of HFNC is its good tolerance. Some patients in respiratory distress receiving high flow oxygen through face masks often tend to pull off their face mask after some time because of discomfort or claustrophobia, and whenever they want to talk or drink. HFNC offers the advantage of enabling oral intake, and patients are able to speak. In addition, nasal cannulae are less often dislodged at nighttime then face masks.[22] Finally, acceptance of the new device by the caregivers was good; it was not found more difficult to set up than ordinary oxygen therapy. Potential indications for HFNC encompass acute hypoxemic respiratory failure, whatever its origin, although, because of the limited PEEP effect with HFNC, patients with severe cardiogenic pulmonary edema should be initially managed with CPAP.[23,24]

Due to preliminary attributes and because we wanted to capture the feasibility and the potential benefits of HFNC as close as possible to the "real life" of the ED setting, this study had several limitations. First, this study is limited by the fact that it was conducted on a small number of subjects with varied diseases and incomplete data. The principal reason for this small sample was the availability of the device because just one device was used. Second, due to the observational nature of the study in an unfavorable environment for clinical research, blood gases were performed in a limited number of subjects. The noticeable increase in S_{pO_2} seen in all the subjects suggests an increase in P_{aO_2} in those subjects in whom arterial blood gases were not performed, even if the magnitude of this increase is unknown. Third, as in other studies on HFNC, we did not measure actual delivered F_{IO_2} or the level of PEEP. Part of the improvement in oxygenation observed with HFNC might thus be related to the delivery of higher F_{IO_2}, in comparison with the face mask. The true delivered F_{IO_2} with these masks is an ongoing quest, and varies considerably, depending on the design of the mask, the flow rate, and the subject's minute ventilation. Given the characteristics of our face mask (non-rebreathing with a reservoir) and the high oxygen flow rates used, we believe that most of our subjects, if not all, had similar F_{IO_2} to those during HFNC. Recently, Roca et al, using similar oxygen flows, made the same assumption.[10] Moreover, this study was not designed to be a randomized or controlled trial, so the ability to compare the improvement between the 2 devices would be prudent. In addition, because of the considerable difference in gas temperature, level of humidification, and interface between the 2 devices, this study could not be blinded.

We are also aware that treatments other than oxygen supply provided in the ED might have contributed to the subjects' improvement. Nevertheless, given the very rapid improvement observed in our subjects, we believe that these other treatments, such as antibiotics in case of pneumonia, would not have had sufficient time to contribute significantly to the observed improvement. A larger scale study is warranted to analyze the effect of HFNC according to the etiology of respiratory distress and perform a sensitivity analysis.

Finally, the clinical relevance of a 3-point decrease in respiratory rate may be questioned. High respiratory rate has been shown, however, as an important predictor of cardiac arrest or critical illness in hospitalized patients.[25,26] Even subtle changes in this often-neglected vital sign[27] may have an important prognostic impact.

Conclusions

Taken together, our results show rapid and sustained alleviation of dyspnea and improvement in oxygenation with HFNC in subjects with respiratory distress presenting to the ED. HFNC was well tolerated, more comfortable, and not more difficult to use than conventional oxygen therapy via a face mask. Our results suggest that HFNC could constitute a first line therapy for selected patients presenting to the ED with acute respiratory failure and underline the need for more data in that setting.

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