RESPIRATORY CARE Articles in Press. Published on March 9, 2012 as DOI: 10.4187/respcare.01575

Humidified high flow nasal oxygen during respiratory failure in the emergency department: feasibility and efficacy

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This work has been presented at the 106° American Thoracic Society meeting, New Orleans, Louisiana, USA, May 2010.

Funding: none

Text word count: 2405

RESPIRATORY CARE Articles in Press. Published on March 9, 2012 as DOI: 10.4187/respcare.01575

CONFLICT OF INTEREST: all authors declare no conflict of interest with a commercial entity related to the study

Keywords: Acute lung injury; Acute respiratory distress syndrome; Dyspnea; Oxygen inhalation therapy; Mouth dryness; Intensive care equipment and supplies

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ABSTRACT

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/mn oxygen or ongoing clinical signs of respiratory distress despite oxygen therapy were included. Device of oxygen administration was then switched from non rebreathing mask to HFNC. Dyspnea rated by the Borg scale and a visual analogue scale (VAS), respiratory rate (RR), and pulse oxymetry (SpO_2) were collected before and 15, 30, 60 min after beginning HFNC. Feasibility was assessed through caregivers' acceptance of the device in terms of practicality and perceived effect on the patients, evaluated by questionnaire.

Results: Seven teen patients, median age 64 (46-84.7) years, 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=0.0004 and VAS from 7 (5-8) to 3 (1-5), p=0.002). RR decreased from 28 (25-32) to 25 (21-28) bpm (p<0.0008) and SpO_2 increased from 90 (88.5-94) to 97 (92.5-100) % (p<0.0001). Less patients exhibited clinical signs of respiratory distress (10/17 versus 3/17, p=0.03). HFNC was well tolerated and no adverse event was noted. Altogether, 76% of healthcare givers declared preferring HFNC as compared to conventional oxygen therapy.

Conclusion: HFNC is possible in the ED, it alleviated dyspnea and improved respiratory parameters in patients with acute hypoxemic respiratory failure.

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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 facemasks) or assisted breathing with non-invasive or invasive mechanical ventilation [3]. In patients who do not require immediate mechanical ventilation, significant drawbacks are associated with conventional oxygen therapy. These include the limited amount of oxygen supplied (15 L/mn is usually the maximum flow delivered via a facemask), the considerable imprecision regarding the exact delivered FiO_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/mn of gas via nasal prongs or cannula under body temperature (37°C) and pressure with saturated water conditions (100% of relative humidity) (Figure 1). Most of the available data with this technique has 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], 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 is 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

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was to determine the feasibility and the effect of HFNC in patients with acute respiratory failure presenting to the ED.

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MATERIAL AND 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 (SRLF) approved of the study and waived informed consent since procedures were all part of routine care. Patients 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 FiO_2 facemask with reservoir (Hudson RCI, Teleflex medical, High Wycombe, UK) 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 facemask, 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 non-invasive 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 facemask. HFNC was delivered via a dedicated high flow delivery system (Optiflow™; Fisher&Paykel, Auckland, New Zealand). HFNC settings were left at the attending physician's discretion but internal discussion with the medical team recommended for most cases a FiO_2 equal or greater than 60% with initial flow of 40 L/min. These settings could obviously be adapted depending on the patient's severity and tolerance of HFNC. Its efficacy was assessed on its capacity to: 1) alleviate dyspnea using the Borg scale [18] and a

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visual analogue scale (VAS) (in those patients whose neurological status allowed them to complete the evaluation), and 2) decrease respiratory rate (RR) and 3) increase pulse oxymetry (SpO_2). All these variables were collected before HFNC while the patient was breathing through the high-FiO_2 facemask and 15, 30, 60 minutes after using HFNC. To keep this study the least invasive, we decided not to systematically sample arterial blood for blood gas assessment. Then, arterial blood gases were performed at the attending physician's discretion, which explains that they were only performed in a subset of patients, before and after HFNC therapy. At the end of the first hour's use of HFNC, patients 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 facemask (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 (model SdB02 class 2 by 01db-Stell). Measures were performed in the room, one meter away from the device. Finally, healthcare givers were asked their opinion of HFNC's preparation and set up and its efficacy; with the same rating as patients: more, less or similar. The feasibility was determined according to these ratings.

Statistical analysis

Statistical analysis was performed using GraphPad Prism 4 (GraphPad Software, San Diego, USA). Results are expressed as median (25-75% percentiles). Friedman test was used to compare paired repeated measurements. Wilcoxon test was used to compare paired measurements. Chi-square test was used for categorical variables. A $p\text{-value}<0.05$ was considered significant.

RESULTS

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During the study period, 386 patients admitted in the ED experienced dyspnea among whom, 17 met the aforementioned inclusion criteria for this study (see Patient flowchart, Figure 2). Median age was 64 (46-84.7) years, and sex ratio 9/8 (female/male). Median Simplified Acute Physiology Score (SAPS2) was 33 (18.5-39.5). Main causes of respiratory failure were pneumonia (n=9), cardiogenic pulmonary oedema (n=4), pneumothorax (n=1), acute asthma (n=1), pleural effusion (n=1), septic shock (n=1). Eight patients' initial neurological status prevented them from fulfilling the Borg and VAS evaluation, which is available for the 9 remaining patients. Median oxygen flow through the facemask prior to HFNC was 15 (10.5-15) L/min. Median SpO_2 was 90 (88.5-94) % and median respiratory rate was 28 (23-32) bpm. HFNC was instituted 94.5 (53.5-139.5) min after patients crossed the emergency room door with a median flow of 40 (30-40) L/min and a median FiO_2 100 (70-100) %. Compared to the variables at H0, while receiving oxygen therapy through facemask, HFNC was associated with a significant decrease in dyspnea intensity in both the Borg score and the VAS as early as 15 min (Table 1). After 15 min, respiratory rate decreased significantly ($p<0.0001$) and SpO_2 increased significantly ($p<0.0001$) (Table 1). These beneficial effects were maintained throughout the study period (Table 1). Less patients exhibited clinical signs of respiratory distress after one hour of HFNC (10/17 versus 3/17, $p=0.03$).

Some patients 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 patients improved so dramatically under HFNC that the attending physician did not require additional arterial blood gases. In the remaining patients (n=6) in whom arterial blood gases were performed before and during HFNC, PaO_2 increased significantly from 61 (56-74) to 129 (96-194) mmHg ($p=0.04$); with no significant changes in pH: 7.40 (7.35-7.44) v. 7.42 (7.35-7.44) ($p=0.8$) or $PaCO_2$: 40 (34.5-47) v. 40 (35.5-46) mmHg ($p=0.9$).

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Nine patients were hospitalized in the ICU and 8 in the ED's short course hospitalization unit. HFNC was continued for all patients admitted to the ICU. Seven were successfully weaned from HFNC after a median time of use of 13.5 (4-34.5) hours and fully recovered. Two required invasive mechanical ventilation and one patient ultimately died. In the ED's hospitalization unit, 5 patients for whom do-not-resuscitate orders had been given died; the remaining 4 patients were ultimately discharged.

Nine patients could give their feeling on the device. All but one stated greater comfort with HFNC than with the facemask. Two of them declared having been disturbed by the noise. Objective sound level measurement indicated that HFHC generated 55dB, oxygen via the facemask 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 facemask. They were 82% to estimate that patients were more comfortable with this device. In terms of set-up and management, 65 % found no difference between HFNC and conventional oxygen therapy, whilst 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 SpO_2) and subjective ones (Borg score and VAS). 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.

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Several factors can account for the beneficial effects of HFNC observed in our study. High gas flow enhances washout of the nasopharyngeal deadspace [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 facemasks often tend to pull off their facemask after sometime 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 cannula are less often dislodge at nighttime then facemasks [22]. Finally, acceptance of the new device by the caregivers was good and 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 closest as possible to the "real life" of the ED setting, this study had several limits. First, this study is limited by the fact that it was conducted on a small number of patients with varied diseases and uncompleted data. The principal reason of this small sample was the availability of the device because of just one device was used and due to the length of utilization even out of the ED. 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 patients. The noticeable increase in SpO_2 seen in all the patients suggests an increase in PaO_2 in those patients 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 FiO_2 or the level of positive end expiratory pressure. Part of the improvement in oxygenation observed with HFNC might thus be related to the delivery of higher FiO_2 in comparison with the facemask. The true delivered FiO_2 with these masks is an ongoing quest and varies considerably depending on the design of the mask, the flow rate and the patient's minute ventilation. Given the characteristics of our facemask (non-rebreathing with a reservoir) and the high oxygen flow rates used, we believe that most of our patients if not all had similar FiO_2s to those during HFNC. Recently, Roca et al, using similar oxygen flow rates, 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 two devices might to be prudent. In addition, because of the considerable difference in gas temperature, level of humidification and interface between the two devices, this study could not be blinded.

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We are also aware that other treatments than oxygen supply provided in the ED might have contributed to the patients' improvement. Nevertheless, given the very rapid improvement observed in our patients, we believe that these other treatments such as antibiotics in case of pneumonia could not have yet contributed 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 a significant prognostic impact.

Taken together, our results show rapid and sustained alleviation of dyspnea and improvement in oxygenation with HFNC in patients 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 facemask. 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.

ACKNOWLEDGEMENTS

Authors would like to thank the nurses and the medical staff of the hospital's ED for their active collaboration to the study.

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LEGENDS FOR FIGURES

Figure 1: Scheme of the HFNC Optiflow® device (Courtesy of Fisher and Paykel).

It consists of an air-oxygen blender with adjustable FiO_2 (21-100%) that delivers a modifiable gas flow (up to 60 L/mn) 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 mgH_2O/L water to the patient via short, wide bore binasal prongs.

Figure 2: Patient flowchart

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Table 1: Changes in dyspnea and respiratory parameters between conventional oxygen therapy and HFNC[1]

Parameter	H_0[4]	$H_{+15\ min}$	$H_{+30\ min}$	$H_{+60\ min}$
Borg scale n=9	6 (5-7)	4 (3-4)*	4 (2-4)***	3 (2-4)***
VAS[2] n=9	7 (5-8)	5 (2-6)*	4 (2-6)***	3 (1-5)**
RR[3] n=17	28 (25-32)	25 (23-30)*	25 (21-30)**	25 (21-28)***
SpO_2 n=17	90 (88.5-94)	96 (90-99)**	95 (90-100)***	97 (93-100)***

* p<.05; ** p<.01; *** p<.001 with Friedman's test

[1]HFNC: high flow nasal cannula; [2]: visual analog scale; [3]: respiratory rate; H_0 denotes the time just before switching from conventional oxygen therapy to HFNC;

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Figure 1

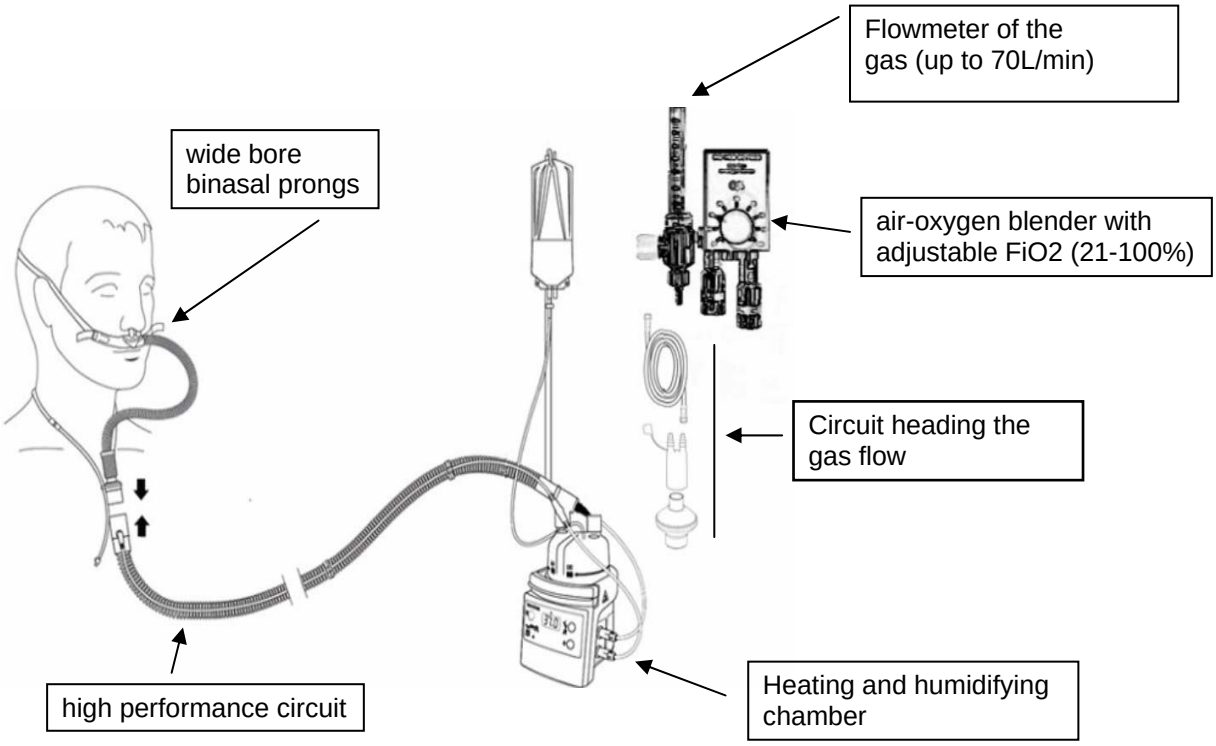

Figure 2