High-Flow Nasal Cannula Oxygen Therapy During Hypoxemic Respiratory Failure

Oxygen therapy remains the first line intervention in acute hypoxemic respiratory failure. Several medical devices for oxygen therapy, which range from simple nasal cannula to non-rebreathing face masks, have been used in the management of acute hypoxemic respiratory failure.[1] The choice of a specific oxygen delivery device is based on the patient's oxygen requirements in terms of flow and desired oxygen concentration, as well as the type of device and its acceptance by the patient.[1] The major challenge for clinicians at the bedside is to be able to provide the adequate, accurate, and stable oxygen requirements to the patients that will alleviate hypoxemia. The traditional oxygen therapy devices are constrained by flow limitation, with flows < 15 L/min, by sub-optimal-humidity, by poor tolerance, and by inaccurate and inconsistent F_{IO_2}.[2] In patients with hypoxemic respiratory failure the patient's inspiratory flow requirements are usually high and very often exceed the oxygen flow delivered by the traditional oxygen devices. This will lead to oxygen dilution and hamper the clinician's capability for delivering consistent and accurate oxygen concentrations for patients in hypoxemic respiratory failure.[2]

High-flow nasal cannula (HFNC) oxygen therapy represents a new alternative to conventional oxygen therapy. In contrast to the traditional schemes for oxygen therapy, HFNC generates flows up to 60 L/min, yet using a nasal cannula as an interface to the patient. These high flows necessitate the optimal conditioning of the breathing gas in terms of humidification and heating to improve patient comfort and the patient's adherence to the therapy. An active form of humidification is generally used during HFNC to condition the high flow gas to optimal heat and humidity (37°C and 44 mg H_2O/L). Also, an incorporated air-oxygen blender allows the delivery of consistent and accurate oxygen concentrations in the range of 21% to 100% to ensure efficient initial management of hypoxemia in patients with hypoxemic respiratory failure.[3]

There are several key therapeutic advantages of HFNC that combine to provide comfortable and efficient respiratory support to patients with hypoxemic respiratory failure. First, HFNC oxygen therapy can meet or exceed the patient's inspiratory flow demand and thus minimize or prevent air dilution, even when the patient is breathing orally.[4] The accurate and consistent delivery of required oxygen concentrations during HFNC eliminates the need to switch among oxygen therapy delivery systems as patients wean off oxygen requirements or their condition becomes more acute. Second, HFNC while delivering high gas flows directly into the nasopharynx can induce a flushing of CO_2 effect in the pharynx. As such, it will create a reservoir of fresh gas that will minimize CO_2 rebreathing, reduce dead space, and increase the alveolar ventilation over minute ventilation ratio.[5] Furthermore, the generated high flows that match or exceed the patients' peak inspiratory flow demands are thought to decrease nasopharyngeal resistance, thereby decreasing resistive work of breathing.[5] Third, recent data suggest that certain levels of positive airway pressure are generated during HFNC therapy (mean airway pressure in the range of 2.7–7.4 cm H_2O).[3,6,7] The degree of pressure generated is dependent on the flow, geometry of the upper airway, breathing through the nose or mouth, and the size of the cannula relative to the nares.[6] Fourth, a recent study by Corley et al confirms that HFNC oxygen therapy generates substantial increases in end-expiratory lung volumes and tidal volumes, particularly in patients with higher body mass index.[8] Finally, by conditioning the high flows delivered to patients with optimal active humidity, HFNC oxygen therapy emulates the balance of temperature and humidity that reduces airway dryness and maintains the function of the mucociliary transport system.[9] Recent studies suggested that the remarkable tolerance of HFNC is attributable in part to the optimal heat and humidity provided during HFNC oxygen to patients with acute hypoxemic respiratory failure.[10-12]

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Recent research has focused on the utility of HFNC oxygen therapy in providing adequate respiratory support in adults, children, and neonates. In a group of 20 adult patients with hypoxemic respiratory failure (S_{pO_2} $< 96\%$ on $F_{IO_2} \geq 50\%$), alternating for 30 min between oxygen face mask over bubble humidifier and 30 min with HFNC oxygen, Roca et al reported that HFNC was associated with less dyspnea and mouth dryness, and was more comfortable.[11] Also, HFNC oxygen therapy was associated with higher P_{aO_2} and lower respiratory rate, but no difference in P_{aCO_2}.[11] These findings were confirmed in another recent study, including 20 patients with moderate to severe hypoxemic respiratory failure (S_{pO_2} = 93.5% with 15 L/min oxygen flow via a face mask).[13] Dani et al[14] conducted a literature review on heated and humidified HFNC therapy in preterm infants and found that heated and humidified HFNC is effective in minimizing nasal mucosa injuries. In 40 premature infants (gestation age 28.7 weeks, weight 1,260 g), Sreenan et al showed that HFNC is as effective as nasal CPAP in the management of apnea of prematurity.[15] Saslow et al compared the work of breathing in 18 premature neonates < 2 kg supported with HFNC and nasal CPAP, and found that HFNC provided ventilator support comparable to nasal CPAP.[16] Also, Holleman-Duray et al evaluated the role of heated and humidified HFNC in decreasing ventilator-induced lung injury in preterm infants (25–29 weeks gestational age).[17] They found that infants extubated to HFNC spent fewer days on the ventilator (11.4 d vs 18.5 d).[17] In bigger patients (newborn to 12 years with median age of 2.8 years and weight range of 0.3–56 kg) treated with HFNC in the pediatric ICU, Spentzas et al showed that HFNC improves the respiratory scale score, the oxygen saturation, and the patient's COMFORT scale.[18]

Little evidence is available on the use of HFNC oxygen therapy outside the ICU setting. In a recent study, Lenglet et al showed that HFNC is feasible and efficient in alleviating dyspnea, decreasing respiratory rate, and increasing oxygen saturation, in 17 adult patients presenting to the emergency department with acute respiratory failure and requiring more than 9 L/min of oxygen flow.[19] Lucangelo et al evaluated the utility of HFNC in patients undergoing bronchoscopy.[20] They randomized 45 patients to receive oxygen at 40 L/min through an air-entrainment mask (n = 15), oxygen at 40 L/min through an HFNC (n = 15), and oxygen at 60 L/min through an HFNC system (n = 15). The highest P_{aO_2}/P_{AO_2}, P_{aO_2}/F_{IO_2}, and S_{pO_2} were achieved with 60 L/min HFNC, with similar bronchoscopy duration and sedation level in all groups. No differences in pH, heart rate, and mean arterial pressure values were found among the groups. These results suggest that HFNC at 60 L/min can be safely applied during bronchoscopy with improved oxygenation.[20] In another aspect of HFNC, a recent report by Boyer et al suggests that heated and humidified HFNC can be well tolerated in a do-not-intubate patient and recommends further studies to elaborate the role of HFNC in palliative care.[21]

In this issue of RESPIRATORY CARE, Cuquemelle et al report a prospective randomized single-center crossover trial of 30 patients in the ICU for acute hypoxemic respiratory failure, aiming to compare the effect of standard oxygen therapy without humidification to heated and humidified high-flow oxygen therapy on nasal caliber and airway dryness.[22] The authors used acoustic rhinometry measurements to determine the cross-sectional area of the nasal cavity, as a surrogate to nasal resistance, in 30 patients with acute respiratory failure, who received, in a crossover design, standard oxygen therapy and actively humidified high-flow oxygen therapy. Discomfort was assessed by evaluating dryness of the nose, mouth, and throat, using a numerical rating scale.

Similar to previous studies,[10-12] Cuquemelle et al confirmed that standard oxygen therapy in patients with hypoxemic respiratory failure is frequently associated with discomfort secondary to nasal dryness, and that the use of heated and humidified HFNC oxygen therapy in these patients significantly decreases the nasal dryness and subsequently improved patients' comfort, tolerance, and acceptance of the therapy. However, the nasal airway caliber did not differ between the 2 groups at any time during the study. It is interesting that at the authors' institution standard oxygen therapy is provided without humidification, particularly in ICU patients.

Although the authors clearly justify this practice, the question remains whether using standard oxygen therapy with no humidification could have placed the patients who were randomized to receive standard oxygen therapy at a disadvantage and as such affected the patients' outcomes and the results of the study. It might have been worthwhile for the authors to have included a group of patients who received humidified standard oxygen therapy rather than non-humidified standard oxygen therapy to obtain another comparison to heated and humidified HFNC oxygen therapy. Also, in their study the authors did not explore other potential benefits for optimal heating and humidification during HFNC oxygen therapy, such as the possibility for decreasing infectious tracheobronchitis and pneumonia, occurrence of microatelectasis, and the irritability of lower airways and bronchospasms. Nevertheless, this study is another testimony for the value of heated and humidified HFNC oxygen therapy in the initial management of ICU patients with hypoxemic respiratory failure.

In conclusion, it is obvious that HFNC oxygen therapy has its role in the management of respiratory distress and failure. HFNC offers a fast and sustained improvement in respiratory parameters in patients with hypoxemic respiratory failure and ensures patient comfort over extended periods of time. However, more data are needed to elaborate more on the mechanisms and use of HFNC inside and outside the ICU in all patient populations with different etiologies of respiratory failures. Specifically, we need large cohort studies aiming at identifying the early predictors of HFNC failure and success and whether the role of HFNC oxygen therapy should be limited only to the initial management of different forms of respiratory failures and whether HFNC oxygen therapy can decrease the need for more aggressive respiratory support such as noninvasive or invasive positive pressure support.

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