ARTICLE IN PRESS
+ MODEL
Pediatrics and Neonatology (2017) xx, 1—8

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: http://www.pediatr-neonatol.com

REVIEW ARTICLE

The Role of Heated Humidified High-flow Nasal Cannula as Noninvasive Respiratory Support in Neonates

Ke-Yun Chao [a,b,c], Yi-Ling Chen [a,d], Li-Yi Tsai [a,e], Yu-Hsuan Chien [a], Shu-Chi Mu [a,f,*]

[a] *Department of Pediatrics, Shin Kong Wu Ho-Su Memorial Hospital, Taipei, Taiwan*
[b] *Department of Respiratory Therapy, Fu Jen Catholic University, Taipei, Taiwan*
[c] *Graduate Institute of Clinical Medical Sciences, College of Medicine, Chang Gung University Taoyuan, Taiwan*
[d] *School of Medicine, Taipei Medical University, Taipei, Taiwan*
[e] *College of Public Health, Institute of Occupational Medicine and Industrial Hygiene, National Taiwan University, Taipei, Taiwan*
[f] *School of Medicine, Fu Jen Catholic University, Taipei, Taiwan*

Received Jan 7, 2016; received in revised form Aug 6, 2016; accepted Aug 15, 2016
Available online ■ ■ ■

Key Words
heated humidified high-flow nasal cannula;
nasal continuous positive airway pressure;
non-invasive positive pressure ventilation;
infant

Recently, heated humidified high-flow nasal cannula (HHHFNC) has been introduced and applied as a noninvasive respiratory support in neonates. Although HHHFNC is widely used in neonates presenting with respiratory distress, the efficiency and safety when compared with nasal continuous positive airway pressure or noninvasive positive pressure ventilation are still controversial. This review aims to evaluate the performance and applications of HHHFNC in neonates.

1. Introduction

Respiratory distress syndrome (RDS) is one of the most common respiratory problems to be encountered in the neonatal intensive care unit (NICU). It is also the leading cause of mortality and morbidity in preterm infants.[1] The oral and nasal cavity of newborns is not only relatively smaller than those of adults but the trachea and bronchi are also shorter, softer, and narrower. When epithelium edema occurs, airway collapse and the internal diameter of bronchi becomes narrower, which leads to respiratory distress in neonates. Symptoms of respiratory distress due

* Corresponding author. Department of Pediatrics, 95 Wenchang Road, Shilin District, Taipei 111, Taiwan.
E-mail address: musc1004@gmail.com (S.-C. Mu).

http://dx.doi.org/10.1016/j.pedneo.2016.08.007

to increased airway resistance include nasal flaring, intercostal retraction, grunting, and paradoxical movement. Moreover, neonates born at a gestational age (GA) of < 36 weeks may have RDS due to the immature lung and lack of surfactant production.

Compared with adults, neonates have a smaller oral capacity and larger tongue, which causes difficulty with breathing through the mouth. The anatomical differences force them to breathe through the nasal cavity most of the time, except when crying.[2]

The establishment of noninvasive respiratory support (NRS), such as nasal continuous positive airway pressure (NCPAP)[3] and noninvasive positive pressure ventilation (NIPPV), will quickly improve the respiratory distress symptoms.[4]

However, complications and irritation from NCPAP and NIPPV have been emphasized, especially iatrogenic damage effects. Recently, heated humidified high-flow nasal cannula (HHHFNC) has been introduced and applied as an alternative NRS.[5] Several studies have suggested that HHHFNC may be as effective as NCPAP and NIPPV.[6–10] The aim of this review article is to identify the role of HHHFNC in neonates.

2. Mechanism of NCPAP

NCPAP was introduced by Gregory and colleagues in 1971,[11] and subsequently became the standard therapy of neonatal respiratory care in the NICU. NCPAP increases functional residual capacity and inflates collapsed alveoli. It also reduces intrapulmonary shunt[12] and increases lung compliance, which in turn improves gas exchange.[13] This helps to stabilize the breathing pattern in preterm neonates.[14] NCPAP also reduces obstructive apnea[15] and decreases airway resistance.[16]

Complications of excessive NCPAP levels may lead to adverse consequences which include air leak syndrome,[17] intraventricular hemorrhage,[18] and decreased cardiac output.[19] Influences of renal function under NCPAP support have been documented, such as diminished urinary output, reduced urinary sodium excretion, and decreased glomerular filtration rate.[20]

However, complications from NCPAP have become more evident as gastric distention, nasal bridge lesions, and patient discomfort due to head-securing devices have been documented. Furthermore, a well-trained nurse is needed in the intensive care setting to perform routine care.[21] Most importantly, the complexity of the ventilator circuit and audible ventilator alarms have been observed to intimidate parents when in close proximity to their child. Compared with NCPAP, HHHFNC is a relatively convenient and comfortable respiratory support.

3. Mechanism of HHHFNC

The HHHFNC system is composed of three parts:

1. *Fixed oxygen concentration system*

To constantly provide a prescribed fraction of inspired oxygen (FiO_2), an oxygen blender or venturi system is required. The prescribed concise oxygen concentrations can reduce the complications of oxygen therapy or risk of oxygen toxicity.[22,23]

2. *Humidification system*

Gas flow must be warm (37°C) and humidified [absolute humidity (AH) of 44 mg/L, relative humidity (RH) of 100%]. During inspiration, the upper airway will be warmed and the unhumidified ambient gas humidified (22°C with AH of 10 mg/L and RH of 50%) to isothermic saturation boundary (ISB; 37°C, AH 44 mg/L, RH 100%).[24–26]

3. *High-flow system*

The high-flow system allows the delivery of a flow rate that exceeds the patient's maximum inspiratory demand. The high-flow rate in infants should be at least 2 L/min and usually 2–8 L/min. A high-flow system can generate nasopharyngeal pressure that reduces airway resistance and work of breath, provides end-distending pressure (EDP), increases functional residual capacity, and improves lung compliance. Wash out of nasopharyngeal dead space contributes to improved alveolar ventilation and enhances the efficiency of gas exchange.[22,23,27–29]

4. High-flow oxygen system

Delivering high-flow gas does not equal high FiO_2, just as delivering a low-flow rate does not equal low FiO_2. A high-flow oxygen system will provide the prescribed FiO_2 as the flow exceeds the patient's demand. Respiratory pattern will not influence the actual partial pressure of inspired for the patient. In a low-flow oxygen system, the inspired partial pressure is unstable as the delivered flow rates are lower than the patient's inspiratory demands, which leads to room air in the oxygen reservoir, in turn reducing the oxygen concentration.[22]

Oxygen is also a kind of drug; for example, it has potential side effect such as retinopathy of prematurity and bronchopulmonary dysplasia.[30] Hyperoxia is associated with a potential harm and major morbidity in neonates. One possible mechanism for hemodynamic alterations of hyperoxia is vasoconstriction.[31] The unintended effect is believed to be the formation of reactive oxygen species.[26,31] In order to avoid hyperoxia, oxygen concentration should be maintained carefully. Animal models also demonstrated that hyperoxia can induce vasoconstriction by acting on L-type calcium channels.[32] Varying oxygenation concentration results in vasoconstriction, subsequent proliferation, and abnormal vascular growth in the retina of preterm infants.[30]

5. Humidification system

Humidification systems contain active humidifiers, heat-wire in the inspiratory limb, and temperature sensors. A humidifier could heat and vaporize the water, which increases the temperature and humidity of delivered gas. The heat-wire and temperature sensor stabilize the temperature under ideal conditions, also preventing condensation inside the circuit.[24,25]

Please cite this article in press as: Chao K-Y, et al., The Role of Heated Humidified High-flow Nasal Cannula as Noninvasive Respiratory Support in Neonates, Pediatrics and Neonatology (2017), http://dx.doi.org/10.1016/j.pedneo.2016.08.007