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The evidence for high flow nasal cannula devices in infants

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EDUCATIONAL AIMS

The article will assist the reader to:

- Increase their knowledge of what constitutes a modern HFNC device, including differences from LFNC and CPAP
- Discuss possible mechanisms of action of HFNC in infants
- Explore the results of clinical studies of HFNC in preterm neonates and infants with bronchiolitis
- Be aware of future areas of research to increase understanding about mechanisms of action of HFNC and to inform best clinical practice and strengthen the evidence base for the use of HFNC

A R T I C L E I N F O

Key words:
High flow nasal cannula
Bronchiolitis
Neonate
Respiratory distress syndrome
Infant
Continuous positive airway pressure
Non-invasive ventilation

S U M M A R Y

High flow nasal cannula (HFNC) devices deliver an adjustable mixture of heated and humidified oxygen and air at a variable flow rate. Over recent years HFNC devices have become a frequently used method of non-invasive respiratory support in infants and preterm neonates that is generally popular amongst clinicians and nursing staff due to ease of use and being well tolerated by patients. Despite this rapid adoption relatively little is known about the exact mechanisms of action of HFNC however and only recently have data from randomised controlled trials started to become available. We describe the features of a modern HFNC device and discuss current knowledge about the mechanisms of action and results of clinical studies in preterm neonates and infants with bronchiolitis. We also highlight future areas of research that are likely to increase our understanding, inform best clinical practice and strengthen the evidence base for the use of HFNC.

INTRODUCTION

The recent development of heating and humidification technology has led to the use of modern humidified high flow nasal cannulae (HFNC) devices as a popular method of respiratory support. For example in neonatal practice, where respiratory illnesses are a major cause of morbidity and mortality, HFNC are often used as an alternative to nasal continuous positive airway pressure (CPAP) [1]. In addition HFNC devices are increasingly being used for a range of applications in paediatric patients with respiratory distress.

CPAP optimises gas exchange by opening alveoli, maintaining mean airway pressure and therefore preventing alveolar collapse [2]. This improves functional residual volume, reduces pulmonary resistance and increases compliance [3]. There is a fine balance, however, between maintaining alveolar patency and preventing over distension. Nasal prongs and facemasks used to deliver CPAP can lead to complications including nasal mucosal trauma, nasal deformity and patient discomfort [4–7]. Other complications include laryngeal dysfunction, gastric distension and practical difficulties with patient handling and nasal prong positioning [4,5,7].

HFNC is relatively less invasive than CPAP, and the ease associated with its use has helped to increase its popularity

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Table 1
Characteristics of LFNC, HFNC and CPAP

	LFNC	HFNC	CPAP
Delivery	Nasal cannulae	Nasal cannulae	Nasal prongs Nasal mask
Flow	$\leq$1L/minute	>1L/minute	Variable
Gas	Unblended Oxygen	Unblended Oxygen *or* Blended oxygen & air	Unblended Oxygen *or* Blended oxygen & air
Temperature	Unheated	Heated	Heated
Humidification	Non-humidified	Humidified	Humidified
Pressure	Minimal	Variable Unregulated	Variable Regulated

amongst nursing staff and carers. A survey carried out in 17 Australasian neonatal units found that the benefits of using HFNC included a reduction in nasal trauma, easier application, better infant-mother bonding, and improved nursing and patient satisfaction [4]. Despite this rapid acceptance, relatively little is understood about its mechanisms of action, and there are a lack of guidelines to assist clinicians regarding application and regulation of its use.

The purpose of this review is to discuss the current understanding of the mechanisms of action of HFNC and to review the existing evidence relating to its clinical applications in neonates and infants.

DESCRIPTION OF HFNC

HFNC devices deliver a blend of humidified high flow oxygen and air at flow rates greater than 1 L/minute. This is different to low flow nasal cannulae (LFNC), which deliver unblended oxygen at flow rates less than or equal to 1 L/minute. With LFNC the oxygen is not humidified or heated and is delivered by standard nasal cannulae [3,8]. In neonatal practice, LFNC is used as a method of weaning respiratory support and for patients with chronic oxygen dependency. LFNC has many uses in paediatric patients with acute and chronic respiratory illnesses that are adequately managed by the low flow provided.

HFNC systems are increasingly used in the preterm population with respiratory distress syndrome (RDS), apnoea of prematurity or as post-extubation respiratory support. In paediatrics, HFNC has a role in the management of acute respiratory infections such as bronchiolitis in infants. The characteristics of LFNC, HFNC and CPAP are summarized in Table 1. Figure 1 shows a diagram of an HFNC device. It consists of a closed system whereby a blend of air and oxygen can be produced at variable gas flows. These gases are heated to near body temperature at 37 °C, humidified and delivered to the patient via nasal cannulae. Several manufacturers currently produce different HFNC circuits and devices, which vary in heating and humidification methods.

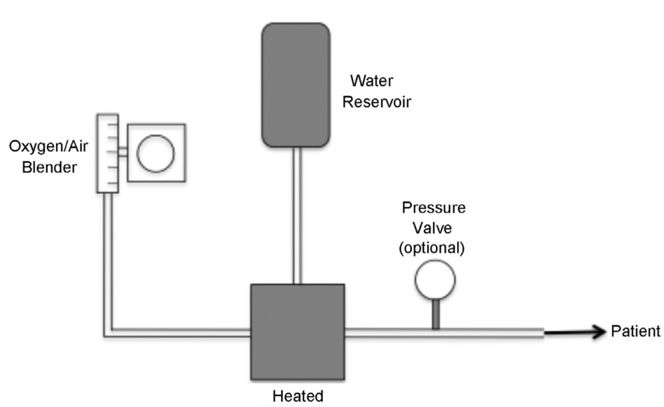

Figure 1. HFNC device circuit.

MECHANISMS OF ACTION

A number of theories exist regarding the mechanisms of action of HFNC and how it is proposed to have clinical benefits associated with its use. Table 2 summarises the results of various physiology studies involving HFNC devices.

Importance of heating and humidification

Delivery of high flow gases without warming or humidification can lead to drying of nasal passages, mucosal injury, patient discomfort, infection, bronchospasm and impaired secretion clearance [3]. Gases delivered by HFNC devices are heated to near body temperature and humidified up to 100% of relative humidity. This has allowed flows as high as 8 L/minute in neonates and 50 L/minute in adults to be used without causing significant irritation to the nasal mucosa [9].

The process of warming and humidifying gases in the nasal mucosa requires energy [10]. This metabolic demand is problematic in patients with reduced pulmonary function whose growth is already recognised to be poor. Following a study to determine the safety and efficacy of a HFNC device, the authors subjectively found an improvement in growth amongst patients treated with HFNC in comparison to those given CPAP. This was felt to be due to reduced energy demands in HFNC patients [5].

Washout of nasopharyngeal dead space

At the start of inspiration, the nasopharyngeal dead space contains end-expiratory gas, which heats and humidifies inspired air but reduces the efficiency of gas exchange. By washing out this dead space, HFNC improves alveolar ventilation and facilitates carbon dioxide removal [10]. Tracheal gas insufflation (TGI) is a method comparable to HFNC that washes out nasopharyngeal dead space with gas inserted by a catheter or endotracheal tube. In ventilated animal models and preterm infants, TGI has been shown to reduce ventilation pressure and volume requirements [1,10]. A reduction in tidal volume, minute ventilation, dead space and $PaCO_2$ was found in a prospective study of spontaneously breathing hypercapnic adults with chronic obstructive pulmonary disease undergoing weaning of mechanical ventilation [11]. In view of these similarities with TGI, HFNC is felt to have similar actions and benefits.

Reduction in upper airway resistance

The nasopharynx has a large surface area, which warms and humidifies inspired gas, but causes a significant increase in inspiratory resistance [10,12]. This resistance is variable, owing to the expandable nature of the nasopharyngeal mucosa [13]. It has previously been demonstrated that CPAP reduces supraglottic resistance by mechanical splinting of the airway with positive pressure [14]. HFNC and CPAP have both been shown to provide similar benefits to work of breathing in neonates [15]. Therefore it is possible that HFNC may also improve inspiratory resistance by stenting the upper airway. Nasopharyngeal gas flow provided by HFNC is similar or greater than the patient's own inspiratory flow, thus improving tidal volume and work of breathing [7,10].