Trends in Anaesthesia and Critical Care xxx (2017) 1–5

Contents lists available at ScienceDirect

Trends in Anaesthesia and Critical Care

journal homepage: www.elsevier.com/locate/tacc

Review

High flow nasal oxygen therapy in adult anaesthesia

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ARTICLE INFO

Article history:
Received 4 July 2017
Received in revised form
18 October 2017
Accepted 7 December 2017

ABSTRACT

High flow nasal oxygen (flow rates of 20–70 L/min) is a relatively new addition to the therapeutic armamentarium of the modern physician. It consists of warmed, humidified mixture of oxygen and air that is delivered at flow rates of typically 20–70 L/min via purpose-built nasal cannulae. This review will focus on important implications of high flow nasal oxygen therapy in adult anaesthesia. We review the development history and current evidence of physiological benefits which are described, as well as recent developments in its uses for adult anaesthesia, including pre-oxygenation and intubation, post-extubation and procedural oxygenation. With new applications for this technology being regularly discovered, it is quickly becoming an essential piece of equipment in modern anaesthetic practice.

Contents

1. Introduction

High flow nasal oxygen (HFNO) therapy consists of a warmed, humidified oxygen/air mixture delivered at flow rates of up to 70 L/min by purpose-built nasal cannulae. The use of HFNO has increased considerably in recent years as it fulfills several previously unmet clinical needs including effective apneic oxygenation and administration of high FiO2 without the need for a tight fitting facemask or endotracheal intubation. Until recently, the use of peri-procedural oxygenation, especially during the intubation period was not a widespread concept. HFNO fills this void in anaesthesia and allows for prolonged apneic periods as well as anaesthesia without a breathing tube to aid surgical access. While several

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https://doi.org/10.1016/j.tacc.2017.12.001
2210-8440/

applications for its use have been described, including paediatric and adult respiratory failure, this review will touch on its history, while focusing on the physiological mechanisms and newly investigated applications in adult anaesthesia. (see Fig. 1)

2. History

Administration of oxygen at higher flow rates has historically been limited by the drying effect on nasal and oropharyngeal mucosa of unwarmed unhumidified gas. Therapeutic administration of warmed humidified oxygen initially began as a method of improving cystic fibrosis secretion clearance. The first commercial system in humans was released by The Oxygen Enrichment company in 1987 [1]. The Transpirator MT-1000 could reach flow rates of 20 L/min. This was followed by several models for exclusive use in racehorses to treat exercise-induced pulmonary haemorrhage. During the late 90s, the advent of humidification enabled a resurgence in development of the technology in humans with the development of Vapotherm 2000i (Vapotherm Inc, Exter, NH). Further developments continued in the 2000s with models released by Salter labs, Smiths Medical and Fisher & Paykel.

Modern HFNO therapy consists of an oxygen/air blender, a heater/humidifier and a delivery system, which may be heated to prevent condensation. Models most commonly available in the UK are MR850 (Fisher and Paykel) and Airvo (Fisher and Paykel). The MR850 requires an oxygen and air supply and can achieve flow rates of up to 70 L/minute. The Airvo requires only an oxygen supply and can achieve flow rates of up to 60 L/minute. Both are compatible with the Optiflow nasal cannula delivery system.

Fig. 1. Fisher & Paykel Optiflow™ HFNO delivery system.

3. Physiology

The exact mechanisms of airflow, oxygenation and ventilation with HFNO are being investigated using computational fluid dynamic modelling. However, several physiological benefits of HFNO have already been demonstrated.

3.1. Humidity

Without achieving adequate humidity and temperature, high nasal oxygen flow rates would very quickly result in drying of the airway mucosa with associated impairment of ciliary function and decreased mobilisation of secretions. Administering an inspired gas with a relative humidity of 100% at 37°C (equivalent to ~44 mg/L absolute humidity) effectively prevents these complications and also minimises respiratory heat and water loss.

Modern high flow nasal oxygen devices can easily achieve close to 100% relative humidity at a temperature of 37 °C at clinically relevant flow rates [2].

3.2. FiO_2

HFNO has the capability to deliver a higher FiO_2 than facemask oxygen due to decreased entrainment of ambient air. FiO_2 delivered by HFNO has been investigated by Sim et al. [3]. Using an oxygen sampling line in the posterior nasopharynx they measured actual FiO_2 delivered by several devices including Hudson mask, non-rebreathing mask and Vapotherm 2000i using 100% oxygen in healthy volunteers. Vapotherm was found to deliver an FiO_2 of 0.89 at 40 L/min compared to an FiO_2 of 0.68 using 15 L/min via non-rebreathing mask. Furthermore, they found that FiO_2 delivered by Vapotherm was not significantly affected when using bandages to decrease chest wall compliance as a simulation of respiratory failure.

3.3. PAP

Positive airway pressure can be beneficial in a number of clinical circumstances due to recruitment of alveoli which minimises atelectrauma. HFNO delivers a low level positive airway pressure that varies with flow rate and whether mouth closed or mouth open breathing is used. Groves and Tobin [4] investigated airway pressures at flow rates of 0, 10, 20, 40 and 60 L/min in healthy volunteers using a Fisher and Paykel HFNO system. They found a linear relationship between flow and expiratory pharyngeal pressure with an increase in pressure from 0.8 to 7.4cmH_2O as flow rates increased from 0 to 60 L/min during mouth closed breathing and from 0.3 to 2.7cmH_2O during mouth open breathing at the same flow rates.

This is supported by work done by Parke et al. [5] in ICU patients comparing the Optiflow system at 35 L/min with standard facemask therapy. They found that in spontaneously breathing patients HFNO generated a mean nasopharyngeal pressure of 2.7 and 1.2 cmH_2O with mouth closed and mouth open respectively. This compares to pressures generated by humidified Hudson mask oxygen therapy (at 35 L/min) of 0.2 and 0.1cmH_2O with mouth closed and mouth open respectively. Further work also by Parke [6] showed that flow rates of 50 L/min provided an average nasopharyngeal airway pressure of 3.1cmH_2O and an average expiratory pressure of 3.8 cmH_2O with mouth closed. There is a clear positive linear relationship between flow and mean airway pressure [7]. For each 10 L/min increase in flow, the mean airway pressure increased by 0.69cmH_2O with the mouth closed and by 0.35cmH_2O with mouth open.

Please cite this article in press as: B.H. Millette, et al., High flow nasal oxygen therapy in adult anaesthesia, Trends in Anaesthesia and Critical Care (2017), https://doi.org/10.1016/j.tacc.2017.12.001