What you need to know about: High flow nasal oxygen therapy

Main introduction

Adequate oxygenation is essential in many disorders, and this article will discuss the physiology, practicalities and indications of high flow nasal oxygen (HFNO) as a novel means of effective oxygen delivery in adults.

What is HFNO?

Several options exist to deliver supplemental oxygen to patients, and each will provide a varying fraction of inspired oxygen (FiO_2). The first distinction to make is between fixed and variable performance devices. In fixed performance devices FiO_2 remains constant regardless of inspiratory flow rates; an example being the Venturi mask system. Variable performance devices deliver a variable FiO_2 depending on the patient's inspiratory flow rate, with examples including nasal cannulae and simple face masks. Increasing flow rates will deliver increasing FiO_2 up to the limitations of the device and patient comfort, with much variation depending on the patient's respiratory pattern. Table 1 summarises the devices available.

Low-flow nasal oxygen via nasal cannulae typically deliver an FiO_2 of 25 to 40% but flow rates greater than 4 L/min may cause patient discomfort. This method of oxygen delivery is appropriate for patients with a low oxygen requirement and is generally well tolerated, as well as being easy to set up and administer at low cost. If the oxygen demands of a patient exceed 40% then ward patients will often be placed on a simple face mask, with a flow rate of 5 to 15 L/min. Further deterioration despite increasing FiO_2 may warrant referral to the intensive care unit (ICU) for close monitoring and timely intubation and mechanical ventilation in the last resort.

High-flow nasal oxygen (HFNO) therapy uses wide bore, soft nasal cannula devices to deliver heated and humidified oxygen at up to 60 L/min, exceeding the patient's peak inspiratory flow rate and thereby acting as a fixed performance device (Nishimura, 2016). In terms of equipment required, most HFNO circuits consist of a flow meter and oxygen/air blender with heated humidifier and nasal prongs. Additional equipment includes a humidification circuit and bacterial filter. Clinical variables which require careful monitoring include continuous oxygen saturations (SpO_2) and arterial blood gas analysis. Within hospitals in the UK, HFNO is often colloquially referred to as 'Optiflow™' which is a brand of Fisher and Paykel Healthcare Limited (Panmure, Auckland, New Zealand). Other brands available include Armstrong Medical Ltd and Vapotherm™ (Solus Medical Ltd). Figure 1 shows the equipment set up of HFNO.

There are no clear guidelines in terms of measuring treatment response to HFNO, however it is important to consider certain measures which indicate treatment failure and warrant urgent clinical review to consider invasive ventilation. Sztrymf et al (2011) suggest that an improvement within one hour of the ratio of partial pressures of arterial O_2 (PaO_2) to FiO_2 ($Pa0_2$:FiO_2 or simply P:F ratio) or PaO_2 alone is a predictor of success. Conversely, absence of improvement in respiratory rate, work of breathing and PaO_2 were early indicators of failure. More simply, a patient may simply report a decrease in dyspnoea. Once established on HFNO, and assuming the underlying condition improves, consideration can be made to wean flow rate before stepping down to conventional oxygen therapy.

Physiology

The use of high flow nasal oxygen is now common in ICU patients with acute hypoxic respiratory failure and in the immediate period following extubation. However the physiological effects of HFNO are still not widely established. Park et al (2009) recorded higher nasopharyngeal pressures with HFNO compared to face mask; most evident when the patient had their mouth closed (mean 2.7 cm H_20). This supports other studies which have asserted a low level of positive pressure generated in the upper airways. This increase in positive end-expiratory pressure (PEEP) will prevent alveolar collapse thereby improving ventilation-perfusion matching and PaO_2 (Chikhani et al 2016).

Mauri et al (2017) investigated the effects of HFNO on several physiological parameters. They used oesophageal pressure swings to show a significant reduction in inspiratory effort and work of breathing, with improvement in oxygenation. This study was also able to estimate changes in lung volume and ventilation, and found that HFNO increased end-expiratory lung volumes and improved lung compliance compared to simple face mask.

Improvement in alveolar ventilation could also be driven by a reduction in re-breathing of expired air. Möller et al (2017) showed that HFNO led to dose-dependent reduction in re-breathing and subsequent reduction in physiological dead space. These findings may explain the decrease in $PaCO_2$ demonstrated by Pilcher et al (2017) in patients with exacerbations of COPD when comparing HFNO to nasal prongs. However the clinical use of HFNO in COPD remains uncertain.

It is likely that high flow nasal oxygen therapy exerts many physiological effects including an increase in PEEP, reduction in dead space and improved lung compliance. Importantly, many studies have found that HFNO is much better tolerated by patients compared to non-invasive ventilation, which may improve compliance. Although more scientific work is needed to characterise the exact physiological effects of HFNO, it appears that it is more than a fixed performance oxygen device.

Indications

Clinical trials looking at HFNO have mainly focussed on its use in acute hypoxic respiratory failure (AHRF) and in those patients extubated following invasive ventilation.

Acute hypoxic respiratory failure

Respiratory failure is a common reason for referral of patients to higher levels of care. There is established evidence supporting non-invasive ventilation (NIV) in patients with hypercapnic (or type 2) respiratory failure with underlying chronic airways disease. Continuous positive airway pressure therapy (CPAP) is established as a treatment for pulmonary oedema secondary to heart failure. The use of NIV or CPAP in non-hypercapnic acute respiratory failure (type 1 respiratory failure), where heart failure is not a cause, is less well understood and has not been proven to be beneficial. For example, Carillo et al (2012) demonstrated an association between delayed intubation and increased mortality in patients with AHRF without underlying cardiac or respiratory disease who were treated with NIV/CPAP.

For many patients an optimum strategy for managing hypoxia and an increased work of breathing has not been defined. Consider a patient with community acquired pneumonia (CAP). There is likely harm from delayed invasive ventilation, if this is indeed inevitable, but there is also harm from invasive ventilation and the associated paraphernalia of critical care. Non-invasive strategies and a period of watchful waiting may minimise harm by reducing physiological strain while waiting, and avoiding premature invasive ventilation for those whose underlying condition will improve with sufficient rapidity. The next section will look at the evidence base behind this strategy, and explore whether HFNO reduces intubation rates and improves mortality.

Frat et al (2015) performed a multi-centre, randomised open-label trial including patients with AHRF without hypercapnia in intensive care units. They assigned patients to standard oxygen therapy, HFNO or NIV for at least two calendar days. Results demonstrated a significant reduction in ICU and 90-day mortality in patients who received HFNO compared to standard oxygen therapy and non-invasive ventilation. The study failed to demonstrate a statistically significant difference in intubation rates between the three groups, except for patients with a P:F ratio of <200mmHg (suggestive of severe respiratory failure) where HFNO was favourable. The authors postulate that the significant reduction in mortality may be attributable to fewer intubations in patients with severe respiratory failure, and call for a larger study to investigate this sub-group.

More recently, Monro-Somerville et al (2017) performed a systematic review and meta-analysis. The meta-analysis included 9 trials with a total of 2,507 patients. The authors found no significant difference in intubation rates or mortality with HFNO. Qualititive analysis showed that HFNO was however well tolerated and improved dyspnoea and comfort scores. Lemiale et al (2017) then looked specifically at

immunocompromised patients with acute hypoxic respiratory failure, and again found no statistically significant difference in intubation rates and overall mortality. Interestingly a prospective, randomised trial of early, intermittent NIV (Hilbert et al 2001) in selected immunosuppressed patients did demonstrate a significant reduction in intubation rates and mortality, however both studies agree that a subsequent randomised study of greater size is required.

The evidence base is therefore inconclusive and it is very difficult to say confidently that HFNO reduces intubation rates and mortality in patients with AHRF. There is certainly a trend in these studies towards favourable outcomes in patients with HFNO, which fall short of statistical significance. The studies agree that HFNO is at least equivalent to other treatments and is better tolerated by patients with improvement in subjective work of breathing and comfort. Despite the paucity of firm evidence, the use of HFNO is becoming more and more common in the intensive care setting and there is much anecdotal evidence of clinical utility.

Pre-intubation

Pre-oxygenation strategies (more precisely, de-nitrogenation of the lung volume) are used in patients undergoing intubation to increase the time between the onset of apnoea at the induction of anaesthesia and arterial desaturation as oxygen stored in the open lung volume is consumed, without replenishment by normal respiration. Again, in theory, HFNO should act as no more than a fixed performance oxygen delivery system during pre-oxygenation. There is evidence of its efficacy (Jaber et al, 2016) but more interestingly Patel and Nouraei (2014) demonstrated efficacy against desaturation that extended well beyond what would be expected as just an oxygen delivery system. In their study, involving the use of a simplified HFNO device on patients with difficult airways (THRIVE) before and following induction of anaesthesia and neuromuscular blockade, no patient desaturated below 90% despite an average apnoea time of 17 minutes. This extended 'apnoeic window' provided a remarkable margin of safety, and the authors conclude that HFNO could be a useful adjunct to anaesthetists during difficult intubations.

Post-extubation

As discussed previously, HFNO can in theory deliver higher concentrations of oxygen compared to conventional oxygen therapy, with improved patient comfort and tolerance compared to NIV. The physiological effects may also improve secretion management, and so would be an ideal therapy to reduce reintubation rates following extubation. Non-inferiority of HFNO compared to NIV has been demonstrated previously (Hernandez et al, 2016) and now several studies have supported the assertion that HFNO used post-extubation on ICU in fact significantly reduces re-intubation rates. Jones and Zappetti (2016) showed a reduction in all-cause re-intubation with HFNO and an associated reduction in post-extubation respiratory failure.

Contraindications

Contraindications to HFNO are similar to non-invasive ventilation (Nishimura, 2016). HFNO is not suitable for unconscious patients (GCS < 8) with absent upper airway reflexes who are at high-risk of gastric aspiration and therefore require a cuffed oral endo-tracheal tube. HFNO is an option in difficult airways due to partial airway obstruction, however will not be effective in complete upper airway obstruction. It should also be avoided in those with epistaxis and basal skull fractures. As with any method of oxygen supplementation, HFNO should be used with caution, or at least under close observation, in patients with hypercapnic respiratory failure where decreased respiratory drive or worsening V:Q mismatch may lead to further increases in arterial $PaCO_2$.

More research is needed into the use of HFNO earlier in the care of patients with hypoxic respiratory failure to prevent admission to ICU altogether, and whether this would improve outcomes such as intubation rate. The appropriateness of the delivery of HFNO in a ward-setting without invasive monitoring is debatable, due to high-risk of deterioration and subsequent intubation and so use should ideally be limited to high-dependency settings or specialist respiratory wards. HFNO could also be an option on medical wards to improve work of breathing in patients unsuitable for ICU admission or those being treated with palliative intent.

Conclusion

HFNO has been rapidly adopted both within and beyond the ICU for patients at risk of respiratory deterioration. It is well tolerated by patients and allows them to talk, and (with care) eat and drink. HFNO offers many benefits over conventional oxygen therapy including the delivery of higher oxygen concentration and provision of low levels of positive airway pressure. It would appear that HFNO exerts significant physiological benefits by directly reducing the work of breathing and reducing respiratory rate thereby improving patient comfort. There is a good evidence base for the use of HFNO in theatres and ICU as an adjunct to both intubation and extubation. Further studies are needed to establish which groups of patients would benefit from HFNO, and to further explore patient outcomes in hypoxic respiratory failure.

Key points

- High flow nasal oxygen delivers up to 60 L/min of humidified oxygen through a nasal cannula
- HFNO appears to provide some positive pressure ventilation and improve physiological measures of work of breathing

- HFNO is often better tolerated than NIV or CPAP delivered by face mask
- HFNO should be delivered in a safe clinical environment with close observation and equipment available for emergency intubation if indicated
- There is no firm evidence of a reduction in intubation rates with HFNO, however some evidence of a reduction in mortality
- There appears to be good evidence for the use of HFNO both before intubation as a pre-oxygenation strategy, and after extubation to reduce reintubation rates

Key words

- High flow nasal oxygen
- Acute hypoxic respiratory failure
- Preoxygenation
- Post-extubation
- Positive pressure ventilation

Table and figures

Delivery device	**Flow rates**	**FiO_2**
Nasal cannula	1 – 4 L/min	24 – 35%
Face mask	>5 L/min	40 – 60%
Venturi mask	Variable	24 – 60%
Non-rebreath reservoir mask	15 L/min	>60%
HFNO	Up to 60 L/min	21 – 80%

Table 1: Comparison of oxygen delivery devices. FiO_2 (fraction of inspired oxygen). L/min (litres per minute). HFNO (high flow nasal oxygen).

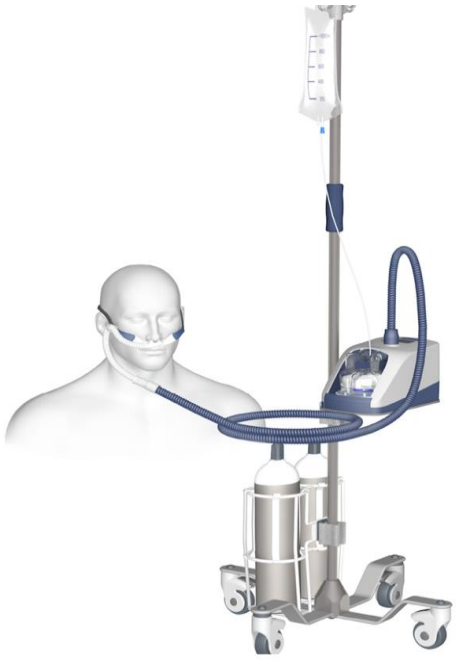

Figure 1: The Optiflow™ system of high flow nasal oxygen. Provided by Fisher & Paykel Healthcare Limited.

Conflict of interest

KP is a regional committee head for the British Journal of Hospital Medicine

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