# High flow nasal oxygen therapy

Adequate oxygenation is essential. This article discusses the physiology, practicalities and indications of high flow nasal oxygen as a novel means of effective oxygen delivery in adults.

## What is high flow nasal oxygen?

Several options exist to deliver supplemental oxygen to patients. The first distinction is between fixed and variable performance devices. In fixed performance devices the fraction of inspired oxygen ($FiO_2$) remains constant regardless of inspiratory flow rates, an example being the Venturi mask system. Variable performance devices deliver variable $FiO_2$ depending on the patient's inspiratory flow rate; examples include 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* summarizes the devices available.

**Table 1. Comparison of oxygen delivery devices**

| Delivery device | Flow rates | Fraction of inspired oxygen |
|---|---|---|
| Nasal cannula | 1–4 litres/min | 24–35% |
| Face mask | >5 litres/min | 40–60% |
| Venturi mask | Variable | 24–60% |
| Non-rebreath reservoir mask | 15 litres/min | >60% |
| High flow nasal oxygen | Up to 60 litres/min | 21–80% |

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Low-flow nasal oxygen via nasal cannulae delivers an $FiO_2$ up to 40% but flow rates greater than 4 litres/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% a simple face mask may be used, with a flow rate of 5–15 litres/min. Further deterioration despite increasing $FiO_2$ may warrant referral to the intensive care unit for close monitoring and timely intubation and mechanical ventilation in the last resort.

High-flow nasal oxygen therapy uses wide bore, soft nasal cannula devices to deliver heated and humidified oxygen at up to 60 litres/min, exceeding the patient's peak inspiratory flow rate and thereby acting as a fixed performance device (Nishimura, 2015). In terms of equipment required, most high flow nasal oxygen 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 and arterial blood gas analysis. Within UK hospitals, high flow nasal oxygen is often colloquially referred to as 'Optiflow' which is a brand of Fisher and Paykel Healthcare Limited. Other brands available include AquaNASE (Armstrong Medical Ltd) and Vapotherm (Solus Medical Ltd). *Figure 1* shows the equipment set up of high flow nasal oxygen.

There are no clear guidelines in terms of measuring treatment response to high flow nasal oxygen, but certain measures indicate treatment failure and warrant urgent clinical review to consider invasive ventilation. Sztrymf et al (2011) suggest that an improvement within 1 hour of the ratio of partial pressures of arterial oxygen ($PaO_2$) to $FiO_2$ ($PaO_2$:$FiO_2$ or simply P:F ratio) or $PaO_2$ alone is a predictor of success. More simply, a patient may report less dyspnoea. Conversely, absence of improvement in respiratory rate, work of breathing and $PaO_2$ are early indicators of failure. Once established on high flow nasal oxygen, and assuming the underlying condition improves, weaning the flow rate before stepping down to conventional oxygen therapy can be considered.

## Physiology

High flow nasal oxygen is now commonly used in intensive care unit patients with acute hypoxic respiratory failure and in the immediate period following extubation. However, the physiological effects of high flow nasal oxygen are still not widely established. Parke et al (2009) recorded higher nasopharyngeal pressures with high flow nasal oxygen compared to face mask, most evident when the patient had his/her mouth closed (mean 2.7 $cmH_2O$). This supports other studies which have asserted that a low level of positive pressure is generated in the upper airways. This increase in positive end-expiratory pressure will prevent alveolar collapse thus improving ventilation–perfusion matching and $PaO_2$ (Chikhani et al, 2016).

Mauri et al (2017) investigated the effects of high flow nasal oxygen on several physiological parameters. They used oesophageal manometry to show a significant

**Figure 1. The Optiflow system of high flow nasal oxygen.**

reduction in inspiratory effort and work of breathing, with improvement in oxygenation. This study was also able to demonstrate that high flow nasal oxygen increased end-expiratory lung volumes and improved lung compliance compared to a 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 high flow nasal oxygen led to dose-dependent reduction in physiological dead space and re-breathing. This may explain the decrease in $PaCO_2$ found by Pilcher et al (2017) in patients with exacerbations of chronic obstructive pulmonary disease when comparing high flow nasal oxygen to nasal prongs. However, the clinical use of high flow nasal oxygen in patients with chronic obstructive pulmonary disease remains uncertain.

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

## Indications

Clinical trials looking at high flow nasal oxygen have mainly focussed on its use in acute hypoxic respiratory failure and in 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 in patients with hypercapnic (or type 2) respiratory failure with underlying chronic airways disease. Continuous positive airway pressure therapy is established as a treatment for pulmonary oedema secondary to heart failure. The use of non-invasive ventilation or continuous positive airway pressure 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 acute hypoxic respiratory failure without underlying cardiac or respiratory disease who were treated with non-invasive ventilation or continuous positive airway pressure.

For many patients an optimum strategy for managing hypoxia and increased work of breathing has not been defined. Consider a patient with community-acquired pneumonia. 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 minimize harm by reducing physiological strain while 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.

Frat et al (2015) performed a multicentre, randomized open-label trial including patients with acute hypoxic respiratory failure without hypercapnia in intensive care units. They assigned patients to standard oxygen therapy, high flow nasal oxygen or non-invasive ventilation for at least two calendar days. Results showed a significant reduction in intensive care unit and 90-day mortality in patients who received high flow nasal oxygen compared to those who received 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 $<200$ mmHg (suggestive of severe respiratory failure) where high flow nasal oxygen 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.

A more recent systematic review and meta-analysis (Monro-Somerville et al, 2017) included nine trials with a total of 2507 patients. The authors found no significant difference in intubation rates or mortality with high flow nasal oxygen. Qualitative analysis showed that high flow nasal oxygen was 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, randomized trial of early, intermittent non-invasive ventilation (Hilbert et al, 2001) in selected immunosuppressed patients did demonstrate a significant reduction in intubation rates and mortality, but both studies agree that a subsequent larger randomized study is required.

The evidence base is therefore inconclusive and it is very difficult to say confidently that high flow nasal oxygen reduces intubation rates and mortality in patients with acute hypoxic respiratory failure. There is certainly a trend in these studies towards favourable outcomes in patients with high flow nasal oxygen, which falls short of statistical significance. The studies agree that high flow nasal oxygen 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 high flow nasal oxygen is becoming more and more common in intensive care 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.

In theory, high flow nasal oxygen 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 (2015) 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 high flow nasal oxygen device in patients with difficult airways 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 concluded that high flow nasal oxygen could be a useful adjunct to anaesthetists during difficult intubations.

### Post-extubation

As discussed, high flow nasal oxygen can in theory deliver higher concentrations of oxygen than conventional oxygen therapy, with improved patient comfort and tolerance compared to non-invasive ventilation. The physiological effects may also improve secretion management, and so would be an ideal therapy to reduce reintubation rates following extubation. Non-inferiority of high flow nasal oxygen compared to non-invasive ventilation has been shown previously (Hernández et al, 2016) and several studies have supported the assertion that high flow nasal oxygen used post-extubation on the intensive care unit significantly reduces re-intubation rates. Jones and Zappetti (2016) showed a reduction in all-cause re-intubation with high flow nasal oxygen and an associated reduction in post-extubation respiratory failure.

## Contraindications

Contraindications to high flow nasal oxygen are similar to those for non-invasive ventilation (Nishimura, 2015). High flow nasal oxygen is not suitable for unconscious patients (Glasgow Coma Scale <8) with absent upper airway reflexes who are at high risk of gastric aspiration and therefore require a cuffed oral endotracheal tube. High flow nasal oxygen is an option in difficult airways caused by partial airway obstruction, but will not be effective in complete upper airway obstruction. It should be avoided in those with epistaxis and basal skull fractures. As with any method of oxygen supplementation, high flow nasal oxygen should be used with caution, or at least under close observation, in patients with hypercapnic respiratory failure where decreased respiratory drive or worsening ventilation–perfusion ratio mismatch may lead to further increases in arterial $PaCO_2$.

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

## Conclusions

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

Figure 1 *is reproduced courtesy of Fisher & Paykel Healthcare Limited.*
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## KEY POINTS

- High flow nasal oxygen delivers up to 60 litres/minute of humidified oxygen through a nasal cannula.
- High flow nasal oxygen appears to provide some positive pressure ventilation and improve physiological measures of work of breathing.
- High flow nasal oxygen is often better tolerated than non-invasive ventilation or continuous positive airway pressure delivered by face mask.
- High flow nasal oxygen 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 high flow nasal oxygen, but some evidence of a reduction in mortality.
- There appears to be good evidence for the use of high flow nasal oxygen both before intubation as a pre-oxygenation strategy, and after extubation to reduce reintubation rates.