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High-Flow Oxygen Therapy (HFOT) in Critical Care

Clinical Information Leaflet

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Ensuring Adequate Tissue Oxygenation in Critically Ill Patients

First line of treatment for hypoxemic respiratory failure

Ensuring an adequate tissue oxygenation is a major goal when treating critically ill patients. The first line of treatment for hypoxemic respiratory failure is oxygen therapy. Supplemental oxygen can be delivered using different devices: low-flow such as regular nasal cannulas or non-rebreathing masks; intermediate-flow such as venturi masks; high-flow devices like high-flow nasal cannula (HFNC).

Low-flow oxygen therapy (LFOT) devices often cause patient discomfort and suboptimal clinical results [1-5]. Supplemental oxygen is generally not humidified when administered at low flow, which may elicit patient complaints such as dry nose and throat and nasal pain, which together with a lower interface intolerance can often lead to low acceptance of this therapy. This unconditioned gas also increases airway resistance by reducing the air flow in the upper airways as well as reducing nasal mucociliary clearance and a limitation of the fraction of inspired oxygen (FiO2) is also observed due to the high inspiratory flow often seen in these patients [6]. Using conventional LFOT, oxygen flow is limited to no more than 15 L/min. Meanwhile, the ideal inspiratory flow for patients with respiratory failure may vary widely in a range from 30 to >120 L/min. There is a large difference between patient inspiratory and delivered flows resulting in a lower than expected, not constant FiO2 with conventional oxygen-flow therapy devices.

The HFNC technology offers the possibility of delivering continuous non-invasive oxygen therapy, for extended periods of time, with more comfort to the patient [4, 5], better oxygenation and clinical outcomes [1-3]. By clinical consensus, the advice is to support the patient through high-flow nasal cannula when PaO2/FiO2 is between 200 mmHg and 300 mmHg. If the PaO2/FiO2 deteriorates to < 200 mmHg, or SpO2 falls below 93%, and/or the respiratory rate is above 30 times/min, then HFOT is not likely to be effective and non-invasive ventilation (NIV) may be a better choice.

If the patient has any of the following symptoms, invasive ventilation should be used instead of high-flow oxygen therapy (HFOT): i) unconsciousness, ii) severe arrhythmia, iii) shock (intravenous norepinephrine dosage> 0.1 µg/kg/min), iv) acute respiratory acidosis (pH < 7.25), v) airway obstruction.

Acute respiratory failure

30% representation of all ICU admissions

40% cases require mechanical ventilation

40% mortality rate

Challenge 1:
Managing acute respiratory failure

Acute respiratory failure (ARF) is a dangerous disease that represents 30% of ICU admissions and has a mortality of around 40% and has not changed significatively over the last years [7, 8]. It has been reported that up to 40% of ARF patients require invasive mechanical ventilation, a technique that is related with many adverse events and complications.

Several studies support the use of HFOT for hypoxemic respiratory failure [9-11], that can help with reduction in the need for endotracheal intubation when compared to COT and NIV [12, 13].

Challenge 2:
Difficult airway management.

A difficult airway was defined in 2013 by the American Society of Anaesthesiologists (ASA) as a clinical situation in which conventionally trained anaesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both [14].

The Difficult Airway Society (DAS) defined difficult airway in 2015 as the inability to obtain effective ventilation after several attempts by an anaesthesiologist with more than five years of clinical experience, during mask ventilation or endotracheal intubation [15].

In any case, identifying a difficult airway is not up to a single definition but it is up to the recognition by the team in charge of the airway to define or institute a protocol or policy to secure the airway appropriately.

In order to avoid the SpO2 from decreasing to dangerous levels during difficult intubation, the acceptable time for each attempt is very short and the number of attempts is limited, therefore the operator is under great pressure when performing intubation.

In obese, obstetric and paediatric patients, the chances of facing a difficult airway management are higher, and even if preoxygenation was sufficient, the SpO2 may drop to 80% within in 4 – 5 minutes [16-18].

Obtaining accurate statistics is challenging but according to studies the incidence of failed intubation varies as follows:

- For elective surgery settings, failed intubation incidence is approximately 1 in every 1000 cases [19],
- During rapid sequence induction (RSI) failed intubation is around 1 in 300 cases [20],
- In the ICU, emergency department, and pre-hospital settings the incidence goes up to 1 in 100 cases [21].

The “Can’ t Intubate Can’t Ventilate” (CICV) scenario occurs in 1 in 5,000 cases for general anaesthesia, and 1 in 50,000 patients will need an emergency surgical airway. It is estimated that 25% of deaths related to anaesthesia are attributed to CICV [22].

HFOT in Improving Oxygen Management

Low-flow oxygen therapy (LFOT) versus high-low (HFOT) for adequate oxygenation

Conventional high-flow oxygen delivery aims to achieve a preoxygenation status before intubation and to support planned extubation. It has conventionally been delivered using nasal cannula or masks, therefore the maximal oxygen flow rates that these devices can deliver are limited to up to 15 L/min, which is far lower than the demands of patients with acute respiratory failure or difficult intubation. Ambient air dilutes the supplied oxygen causing a significant reduction of the FiO2 in the alveoli. Furthermore, oxygen delivered by low-flow systems hardly meets the requirements of heating and humidification in these patients [23].

High-Flow Nasal Cannula (HFNC) oxygen is an oxygen supply system capable of delivering up to 100% humidified and heated oxygen at a constant flow rate of 60 liters per minute and eventually higher [23].

	LFOT	HFNC
Clinical scenario	Oxygenation	Pre-intubation, post-extubation, ARF,palliative care
Safe apnea time	6-8min (Adult)	Up to 30 min (Adult)
Flow rate	1-15L / min	Up to 60L / min or higher
FiO2	Usually 100%	21 %-100%, adjustable,constant
Interface	Mask	High flow nasal cannula
Device	Wall flow meter, Ventilators	Standalone device, Ventilator with HFNC function
Actvice humidifier	No need	Recommended

Physiological effects of HFOT

Increased inspired fraction of oxygen

The inspired fraction of oxygen (FiO2) delivered to the patient can reach up to 100% with NIV but it is usually not higher than 70% with standard oxygen. This observed drop in FiO2 is related to the fact that oxygen is mixed with room air, a dilution effect that is minimised when using HFOT. By comparison FiO2 when using HFOT can be as high as 85%, leading to better oxygenation [24].

PEEP effect

HFNC oxygen delivery creates a positive airway pressure that increases end respiratory lung impedance in spontaneous breathing patients, which is consistent with an increase in end-expiratory lung volume and functional residual capacity. It also assists with upper airway patency, as observed in patients with obstructive sleep apnoea, who have less inspiratory flow limitation with nasal insufflation [25].

Low level positive pressure can be achieved delivering a high concentration of oxygen using HFNC at 35 litres per minute with mouth closed [26]. Also, it is known that there is a positive linear relationship between flow and pressure, therefore the mean nasopharyngeal pressure during nasal high-flow oxygen increases as flow increases [27].

Dead space flush

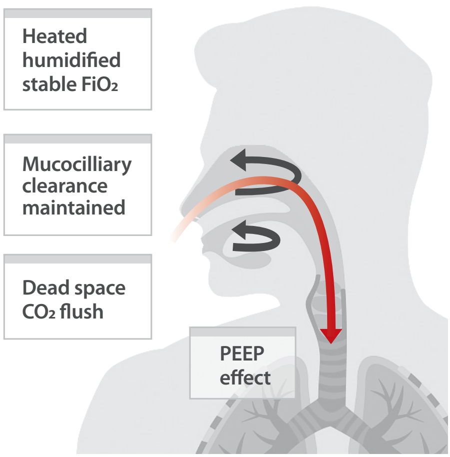
Expired air flushing in upper airways can be extended below the soft palate with a reduction of dead space. HFNC oxygen promotes washout of gases from anatomical dead space, including more distal conducting airways, this was demonstrated by scintigraphy studies in breath-holding subjects and by direct measurement of carbon dioxide and oxygen in the trachea confirmed a reduction of rebreathing [28, 29].

Mucociliary clearance

Conventional oxygen delivery systems often have significant adverse effects on the function of the mucocilliary transport system leading to impaired defence of the airway and gas exchange. Delivering essential humidity through HFNC can prevent the inflammatory response caused by the drying of the mucosa. Conditioning of the gas can also minimize airway constriction, reducing the work of breathing, which helps to maintain effective delivery of oxygen to the lungs. By delivering optimal humidity, patients can maintain the function of the mucociliary transport system, clearing secretions more effectively and reducing the risk of respiratory infection [30].

Improved patient comfort

Most studies found that patients treated with HFOT feel better comfort, less sensation of dyspnoea as well as less dryness of mouth when compared to LFOT [2, 11]. Comparison with NIV also show less discomfort and less breathlessness [31].



Which Are the HFNC Oxygen Applications to Increase Safety in Critically Ill Patients?

High risk patients	Ventilation weaning and extubation
• Acute respiratory failure • Obese patients • Paediatric Patients • Difficult airway management • Palliative care in ICU	• Ventilation weaning • Risk of re-intubation

High-risk patients

Obese, neonates and paediatric, pregnant, septic and critically ill patients are at a higher risk of showing a reduced oxygen reserve.

Obese patients

The World Health Organisation (WHO) estimates that more than 300 million people are affected by the so called "Globesity epidemic". Morbidly obese patients have a reduced functional residual capacity with consecutive increased incidence of atelectasis. The ventilation/perfusion mismatch leading to hypoxemia by shunting, in these cases, preoxygenation enhances the safety margin for placement of the endotracheal tube [32].

Paediatric patients

The onset of desaturation in apnoeic children occurs much faster than in adults and is known to be age dependent. Children have a smaller functional residual capacity than adults, have a greater metabolic demand, generating a higher CO_2 output, and have a greater tendency for airway collapse [17].

A recent prospective study of all emergency intubations occurring in a tertiary paediatric emergency department showed that only 78% of intubation attempts were successful at the first attempt, with 14% having an adverse desaturation event. It was also observed that trans-nasal humidified rapid insufflation ventilatory exchange achieved with HFNC prolongs the safe apnoea time in healthy children but has no effect to improve CO_2 clearance [17].

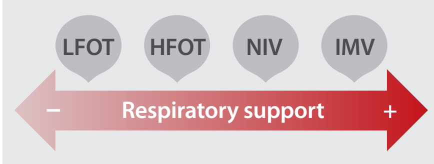
Palliative care in ICU

End-of-life palliative care patients often suffer from respiratory distress. They are challenging to treat since most cases have a "do not intubate" status, and non-invasive positive pressure ventilation is uncomfortable or intolerable for many. In 2004, the expert working group of the scientific committee of the association of palliative medicine proposed that oxygen therapy be prescribed for patients with advanced cancer if it can alleviate the symptom of breathlessness [33].

Ventilation weaning and extubation

A critical point for patients under invasive mechanical ventilation (IMV) in ICU comes with extubation once the cause of respiratory failure is treated. Extubation failure rate is around 10-15% and may exceed 20% in patients at high risk. The mortality for those failed extubation cases is around 40% [34-36], therefore optimizing mechanical ventilation weaning is essential. Premature weaning increases ventilation and mortality rates whereas delayed weaning increases risk of adverse events related to mechanical ventilation as well as the cost of the therapy [37, 38].

Several studies indicate that applying prophylactic NIV within the first 24 to 48 hours after extubation could reduce the risk of respiratory failure in patients at high risk [39-41]. The most recent European and American



clinical practice guidelines suggested that NIV could be used to prevent postextubation respiratory failure in patients at high risk [42].

High-flow oxygen therapy has showed to reduce the risk of reintubation (5%) when compared to conventional post-extubation oxygen therapy (12%) in a randomised clinical trials with patients at low and high risk for reintubation [1, 2]. A recent randomised clinical study in 2019 showed that high-flow oxygen therapy can reduce both the time needed to wean patients from mechanical ventilation and reduce reintubation rate [43].

Striving for the best practise towards Patient Safety in Intensive Care settings, Mindray incorporates High Flow Nasal Cannula (HFNC) oxygen to the SV-series Ventilators, which contributes to a safer patient management by addressing potential complications related to hypoxemia in critically ill patients and difficult airway management.

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