mysafety insight

High Flow Nasal Cannula(HFNC) Oxygen in Anaesthesia

Clinical Information Leaflet

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Avoiding Hypoxemia during Anaesthesia

What is the risk?

During surgery, there is a potential risk of being exposed to a prolonged apnoea followed by an arterial haemoglobin desaturation. Preoxygenation using 100% oxygen before the anaesthesia induction is highly recommended to delay the onset of arterial haemoglobin desaturation during prolonged apnoea [1].

Based on a large retrospective study carried out at two hospital sites, 95,407 electronic anaesthesia records were analysed, finding that during the intraoperative period, 6.8% of patients had a hypoxemic event and 3.5% of patients presented a severely hypoxemic event of two consecutive minutes or longer. From the same study it was observed that 70% of the hypoxemic episodes occurred during either induction or emergence, time periods that represented 21% of the total intraoperative time [2].

In another study that aimed to determine the incidence of inadequate preoxygenation in a large, unselected population in a clinical setting (defined below in more detail as FeO_2 < 90% after a 3-min tidal volume breath), from a sample of 1,050 patients, inadequate preoxygenation was observed in 589 (56%) [3].

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

6.8% of patients presented a hypoxemic event during surgery

3.5% of patients presented a severe hypoxemic event of two consecutive minutes or longer during surgery

70% of hypoxemic episodes occurred during either induction or emergency

56% Incidence of inadequate preoxygenation

The challenge of a difficult airway management

In 2013, the American Society of Anesthesiologists (ASA) defined a difficult airway as the clinical situation in which a conventionally trained anaesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both [4].

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 [5].

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

In order to avoid SpO_2 decrease to a dangerous level during difficult intubation, the time allowed for each attempt is very short and the number of attempts is limited, therefore the operator is under great pressure.

In obese, obstetric, and paediatric patients, the chances of facing a difficult airway are higher. Even if preoxygenation is sufficient, SpO_2 drops to 80% in only 4 to 5 minutes [6,7,8].

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

- For elective surgery settings, failed intubation incidence is approximately 1 in every 1,000 cases [9];
- During rapid sequence induction (RSI), failed intubation is around 1 in 300 cases [10];
- In the ICU, emergency department, and pre-hospital settings, the incidence increases to 1 in 100 cases [11].

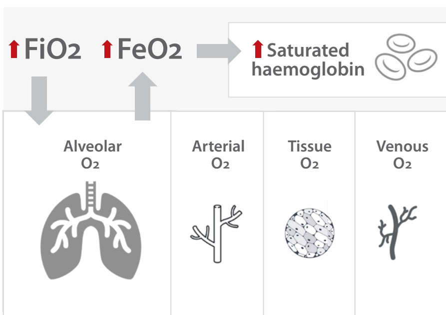
The "Can' t Intubate Can' t Ventilate" (CICV) scenario occurs in 1 in 5,000 cases for general anaesthesia. About 1 in 50,000 patients will need an emergency surgical airway. It is estimated that 25% of deaths related to anaesthesia are attributed to CICV [12].

The most feared and serious complications of a difficult airway management are death, cardiopulmonary arrest, brain injury, and airway trauma.

Preoxygenation/Denitrogenation to Minimise Risks

Preoxygenation/Denitrogenation

The load of oxygen during preoxygenation depends on factors that relate to alveolar, arterial, tissue, and venous compartments, however most of the oxygen is stored in the lungs as Functional Residual Capacity (FRC), therefore the main goal of preoxygenation is to maximise the alveolar fraction of oxygen which depends on the effective fraction of inspired oxygen (FiO_2) delivered. When most of the pulmonary nitrogen is replaced by oxygen, the FeO_2 is increased to a value slightly over 90% and preoxygenation is successfully achieved [2].



The most recommended technique to guide and achieve an efficient preoxygenation is to deliver 100% oxygen for 3 minutes using a standard breathing system with the goal of achieving $FeO_2 > 90\%$. There is a correlation between the FeO_2 reached and the subsequent apnoea time that can be achieved without haemoglobin desaturation [12].

The three main goals of preoxygenation are [13]:

1. Achieve 100% oxygen saturation prior to the anaesthetic procedure.
2. Denitrogenate the FRC of the lungs to maximise oxygen storage.
3. Denitrogenate and maximally oxygenate the bloodstream.

Conventional Preoxygenation versus High Flow Nasal Cannula (HFNC) oxygen

Conventional preoxygenation aims to achieve a preoxygenation status before an anesthetic procedure 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 liters per minute, 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 FiO_2 in the alveoli. Furthermore, oxygen delivered by conventional preoxygenation hardly meets the requirements of heating and humidification in these patients [14].

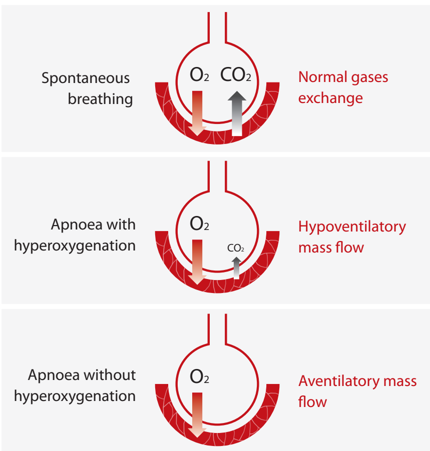
High flow nasal cannula (HFNC) oxygen is an oxygen supply system capable of delivering up to 100% humidified and heated oxygen at a flow rate of 60 liters per minute and eventually higher [14].

	Conventional Preoxygenation	HFNC
Clinical scenario	Pre-oxygenation	Pre-intubation, post-extubation, tubeless anaesthesia, deep sedation
Safe apnea time	6-8min (Adult)	Up to 30 min (Adult)
Flow rate	1-15 liters per minute	Up to 60 liters per minute or higher
FiO_2	Usually 100%	21 %-100% Adjustable
Interface	Mask	High flow nasal cannula
Device	Wall flow meter, Anaesthesia delivery station (manual mode)	Standalone device, Anaesthesia delivery station with HFNC function
Actvice humidifier	No need	Recommended

Physiological Effects of HFNC Oxygen

Apnoeic oxygenation

When apnoea occurs, the oxygen extraction from the alveoli to the arterial blood flow develops into a decrease of interalveolar pressure that becomes subatmospheric. This situation generates a pressure gradient that allows more oxygen to passively move into the alveolar space [15,16], known as "aventilatory mass flow" [17]. Apnoeic oxygenation is achieved by administering HFNC oxygen and removing the nitrogen that otherwise would be accumulated in the lung and, combined with the carbon dioxide accumulation, diminishes the available pressure gradient for oxygen transfer to the alveolus and hastens the onset of hypoxaemia [18].



Apnoeic oxygenation may prolong safe apnoea time and increase first-pass success during emergency intubation [19].

PEEP effect

HFNC oxygen delivery creates positive airway pressure that increases 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 [20].

Low level positive pressure can be achieved delivering a high concentration of oxygen using HFNC at 35 litres per minute with mouth closed [21]. Also, as there is a positive linear relationship between flow and pressure, the mean nasopharyngeal pressure during nasal high-flow oxygen increases as flow increases [22].

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, wherein direct measurement of carbon dioxide and oxygen in the trachea confirmed a reduction of rebreathing [23,24].

Which are the HFNC oxygen applications to increase patient safety in anaesthesia?

Induction & Intubation	Tubeless anaesthesia	Recovery & Post-anaesthesia
• Obese patients • Paediatric patients • Obstetric patients • Difficult airway management • High-risk patients (critically ill)	• Procedural sedation and short surgical procedures • Shared airway (ENT surgery)	• Risk of re-intubation • High-risk patients (critically ill)

Induction and Intubation

▸ Obese patients

The 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. In cases where, ventilation/perfusion mismatch leads to hypoxaemia by shunting, preoxygenation enhances the safety margin for induction of general anaesthesia and placement of the endotracheal tube [25].

▸ 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 [8].

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 HFNC oxygen prolongs the safe apnoea time in healthy children but has no effect to improve CO_2 clearance [8].

▸ Obstetric patients

Failed airway management in an obstetric patient undergoing general anaesthesia is associated with major sequelae for the mother and/or foetus. Therefore, effective and adequate preoxygenation is recommended in all current major airway guidelines. HFNC oxygen may have theoretical benefits if used for preoxygenation and apnoeic oxygenation in pregnant patients [28].

Difficult airway management

Preoxygenation using HFNC demonstrated to be useful to maintain oxygen saturations after commencement of apnoea. It has been found to also change the nature of difficult intubations from a "hurried stop-start" to a smoother event undertaken within an extended safe apnoeic window [4-11,27].

The use of HFNC oxygen for preoxygenation of high-risk patients undergoing awake fibreoptic intubation (AFOI) minimises the risk of hypoxaemia and makes AFOI an inherently safer procedure [28].

In patients undergoing rapid sequence induction of anaesthesia, the mean apnoea time (and therefore intubation time) was 125s longer in those preoxygenated with HFNC. This was not due to apparent differences in procedural difficulty [29].

High-risk patients (critically ill)

Continuous nasal oxygenation (low flow or high flow), is part of 'Plan A' in the first iteration of the Difficult Airway Society guidelines for tracheal intubation of critically ill adults [30].

Nasal oxygen can be used during both preoxygenation and perioxygenation. If standard nasal cannula is used, these should be applied during preoxygenation with a flow of 5 liters per minute while awake, increased to 15 liters per minute when the patient loses consciousness [31].

Tubeless anaesthesia

Procedural sedation and short surgical procedures

Apnoeic oxygenation with high-flow nasal oxygen has also enabled tubeless anaesthesia for extended periods of time [15,32-34].

Shared airway (ENT surgery)

In shared airway procedures, the anaesthetist needs to maintain the patient airway for optimal oxygenation and carbon dioxide removal while the surgeon requires certain access to the area. These kind of procedures are common in patients undergoing ear, nose, and throat (ENT) interventions like maxillofacial and dentistry surgery under general anaesthesia.

It has been observed that HFNC oxygen under apnoeic conditions can provide satisfactory gas exchange during tubeless anaesthesia for laryngeal surgery [33], and more concretely, in patients with mild systemic disease and a BMI<30, the apnoea time can reach 30 minutes [32]. In endoscopic balloon dilation of subglottic stenosis, the HFNC oxygen allows excellent visualisation and surgical access with less interruptions of the procedure [35].

Striving for best practise towards patient safety in anaesthesia settings, Mindray incorporates high flow nasal cannula (HFNC) oxygen to the A8/A9 anaesthesia workstations, which contributes to safer patient management by addressing potential complications related to hypoxaemia during anaesthetic procedure and difficult airway management.

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