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Review Article

High flow nasal cannula (HFNC) as a pillar to aid oxygenation perioperatively: A narrative review

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ABSTRACT

High flow nasal cannula (HFNC) has gained popularity in recent years as a reliable method to deliver warmed and humidified oxygen at high flows through nasal cannulae. HFNC by virtue of its convenient application, enables compliance and thus is being increasingly used for oxygenation in adult as well pediatric patients. HFNC should ideally be used in a monitored setting such as an intensive care unit, a high-dependency unit and the emergency department. The advantages of HFNC compared with conventional oxygen therapy include delivery of a predictable FiO2, better humidification, decreased anatomical dead space, and improved patient comfort. The concern of aerosol generation with HFNC led to its restricted use during the COVID-19 pandemic. The application of HFNC is multidimensional and ranges from providing respiratory support in the intensive care unit to perioperative use in the operating room (OR) and the post-operative care unit. In the OR, HFNC is used for preoxygenation before tracheal intubation, for apneic oxygenation during laryngoscopy, bronchoscopy, or difficult airway management, for postoperative oxygenation to avoid reintubation and postoperative pulmonary complications (PPC's). The efficacy of HFNC for postoperative oxygenation has been mainly evaluated in patients following cardiac and thoracic surgery, as they are at risk for development of PPC's. This review discusses the practical considerations and clinical utilities of HFNC in the perioperative period, including vulnerable patient groups that are the elderly, obese, in patients with an anticipated difficult airway, situations where rapid sequence induction is essential and in patients with the risk of postoperative respiratory failure.

1. Introduction

High flow nasal cannula (HFNC), a non-invasive respiratory aid has become prominent when compared to other types of non-invasive respiratory assist devices, such as continuous positive airway pressure (CPAP) or non-invasive ventilation (NIV). This is due to its ability to deliver a significant fraction of heated and humidified oxygen at high flows via the nasal route. [1,2] It enhances the patient's comfort by virtue of its easy application while the heat and humidification help in the removal of airway secretions as well as avoid desiccation and epithelial injury. [3–5]

NIV is primarily useful in patients with acute hypercapnic respiratory failure due to an exacerbation of chronic obstructive pulmonary disease or acute cardiogenic pulmonary edema. The NIV interfaces add to anatomic dead space; whereas, HFNC decreases dead space.

During the pandemic, HFNC played a vital role in managing corona virus- induced (COVID-19) patients with moderate-to-severe acute hypoxemic respiratory failure (AHRF). The important concerns related to its use were the likelihood of infection transmission to healthcare personnel

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due to bioaerosol dispersion like with other modes of NIV and the requirement of higher oxygen flow.[6–8] These factors led to its limited and controversial use during COVID-19 pandemic. In addition, there has been inadequate scientific evidence supporting its use in patients of COVID-19 associated (AHRF).[9–13] The acute oxygen crisis during the second wave of the COVID-19 pandemic also led to limited use of HFNC in the Indian subcontinent.

The literature is replete with studies evaluating the role of HFNC in the management of AHRF in critically ill patients.[2,8,14–16] However, post-COVID pandemic in the last few years, HFNC oxygen therapy utilization has been extensive, especially in numerous non-intensive care unit (ICU) scenarios i.e. for pre-oxygenation before orotracheal intubation,[17] apneic oxygenation during the difficult airway management[18] and postoperative oxygen therapy.[19] The present narrative review aims to summarize the existing evidence with regard to its clinical application for providing oxygenation in non ICU setting i.e. operation theatre and post operative area.

1.1. Search strategies

The authors conducted a comprehensive literature search using PubMed, MEDLINE, EMBASE, and Google Scholar from January1^{st} 2014 till April 30^{th}, 2024. The search strategy in PubMed included a literature search with the following keywords (HFNC OR HFNO) AND with either (preoxygenation), (apnoeic oxygenation), (preoxygenation AND apnoeic oxygenation) or (postoperative oxygenation). This policy was then further adapted for other databases. Articles in the English language were included. Initially, the titles and abstracts were reviewed, following which full-text articles were retrieved depending on their relevance to this review. (Figure 1) All the articles were read by the two authors (G.T.C. and MG), and any discrepancies were resolved by consensus with the third author. Interventional, observational data, case reports/series, reviews and meta-analyses were included in this narrative review.

1.2. HFNC: Overview

HFNC involves delivery of an adjustable mixture of heated and humidified air and oxygen at rates that exceed the spontaneous inspiratory flow. It is also known as HHHFC i.e. Heated, humidified, high flow nasal cannula. Improved patient comfort and oxygenation are the major attributes of this device.

The two parameters needed to be set are the flow rate and the fraction of inspired oxygen (FiO2). First flow rate is set to 20-35L/minute (range 5-60 L/min).

The Fi02 (21-100%) is the next target to achieve the desired peripheral oxygen saturation. Heat and humidification help in preventing airway desiccation which further facilitates the removal of secretions. The high flow of oxygen helps to flush out the nasopharyngeal dead space, helping improve oxygen delivery and ventilation, additionally ensuring consistent and reliable delivery of a fraction of inspired oxygen. The positive end-expiratory pressure provided by HFNC, helps to further improve the oxygenation by reducing the work of breathing.[20–22]

1.3. Clinical utility of HFNC

Application of HFNC should be done in monitored care settings like the ICU, high dependency unit, operating room, or in the emergency department.[23]

The use of HFNC started with its use for management of AHRF in ICU setting. The clinical improvement with other modes of oxygen therapy like NIV is variable and conflicting evidence exists in its beneficial effect over that of HFNC in patients with AHRF.[24–29]

It is also widely used for providing oxygen support in children with bronchiolitis who are at a risk for progression to respiratory failure by reducing the work of breathing, improving gas exchange, and thus avoiding endotracheal intubation.[30–32]

COVID -19 induced AHRF is another setting where HFNC was widely employed during the pandemic. It was observed that HFNC decreases the need for mechanical ventilation[10] and lowers intubation rates;[11] however, no reduction in the 28-day mortality or ventilator-free days[11] or likelihood of escalation of respiratory support[12]$when$ compared with COT. Research articles comparing NIV with HFNC in the setting of COVID-19 are limited to a few RCTs only.[8,13,14] None of these studies established the superiority of HFNC over other modalities in terms of intubation or mortality rates. The ancillary applications of HFNC include its role as an aid in bronchoscopy[33] or for tracheal extubation of high-risk patients.[34]

The increasing availability of HFNC following the COVID pandemic led to its extensive use in the operating room (OR) as viewed by an acute surge in research articles over the past few years. In the OR, HFNC is used for preoxygenation before tracheal intubation, for apneic oxygenation during laryngoscopy, bronchoscopy, or difficult airway management, and for postoperative oxygenation to avoid reintubation and postoperative pulmonary complications (PPCs).

2. Discussion

2.1. HFNC for Apneic oxygenation

Apneic oxygenation (ApO) prolongs the safe apnea time and is used during laryngoscopy, bronchoscopy, rapid sequence induction (RSI), management of difficult airway (DA), and in the form a primary anaesthetic technique for laryngeal surgeries. The advantage of HFNC is that it does not hinder access to the airway and the disadvantage being that it impairs the facemask seal; without, an established

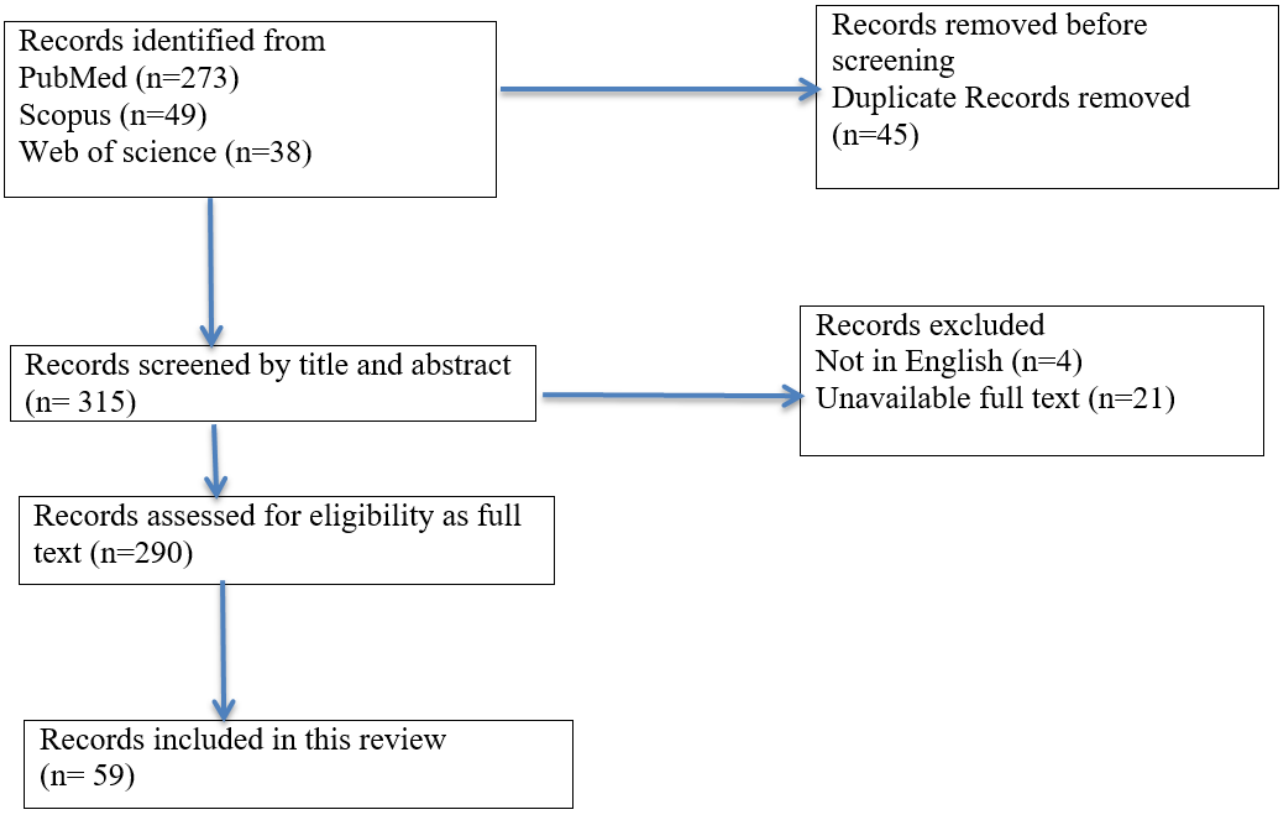

Diagram 1: Search strategy flowchart

position as a rescue technique for oxygenation in the already desaturating patient.

The mechanism of ApO using unwarmed, dry oxygen via standard nasal cannulae at 15 l/min is termed as Nasal Oxygen During Efforts At Securing a Tube (NODESAT).[35] Similarly, Transnasal Humidified Rapid Insufflation Ventilatory Exchange (THRIVE) works on the mechanism of ApO using heated and humidified oxygen.[36] The mechanism with which HFNC leads to ApO is known as "aventilatory mass flow". During apnea, oxygen is drawn from the alveoli to the blood this leads to negative alveolar pressure and thus movement of oxygen from the pharynx into the alveoli. The HFNC here has the advantage of providing higher FiO2 along with positive airway pressure.

THRIVE is also used for "tubeless anesthesia'. The latter is a ventilatory technique that allows avoidance of tracheal intubation or jet ventilation in a few chosen laryngeal surgical cases when used intraoperatively. It provides the surgeon with a patient being completely along with an unobstructed view of the larynx. In addition, there is an unhindered approach to all parts of the glottis leading to better surgical precision, decreased operative time, and improved patient prognosis. Literature is replete with articles evaluating THRIVE for tubeless laryngeal surgery. THRIVE has been found to be safe for intraoperative oxygenation in designated patients undergoing nonlaser laryngologic surgery of short-to-intermediate duration.[37,38] Recently, a meta-analysis has concluded that HFNC may be as effective as tracheal tubes in terms of providing oxygenation during laryngeal surgery but they suggested that conventional ventilation with tracheal intubation may be safer.[39]

2.2. *HFNC for preoxygenation*

Abundant literature is available, evaluating HFNC/THRIVE for preoxygenation (PO) before induction of anesthesia. Most of these studies have been conducted in obese patients,[40–44] patients undergoing RSI[18,45,46] and anticipated DA management.[34] In addition, the HFNC has also been used for preoxygenation in patients undergoing gastrointestinal surgery,[17] neurosurgical procedures,[47] in pediatric patients[48,49] and in the elderly.[50,51]

The efficacy of PO utilizing HFNC in obese patients is not clearly established. In this subgroup, HFNC has been compared to various methods of PO. One study claimed a face mask (FM) with positive end-expiratory pressure to be superior to HFNC for PO in obese subjects.[52] On the other hand, the one comparing it with NIV observed that

HFNC in patients with obesity resulted in lower end-tidal oxygen after intubation and a higher rate of desaturation < 95%[53] similarly, on comparison with oxygen delivered via nasal prongs at 4 L min^{-1}, with Optiflow THRIVE™ at a flow rate of 70 L min^{-1}, a prolonged safe apnoea time pertaining to the latter was observed; however, the results were inconclusive.[54]

A meta-analysis evaluated HFNC for PO and ApO in the obese population and concluded no difference between HFNC and FM for PO in preventing oxygen desaturation (<92%) or lowest oxygen saturation before intubation.[55] However, the limitations of the study include a small sample, specific patient population, use of various FM preoxygenation techniques amongst different trials.

A recent met-analysis to evaluate the role of HFNC versus conventional oxygen therapy (COT) during the perioperative period in obese patients concluded that the former reduced the incidence of hypoxemia, need for additional respiratory support and the length of hospital in this particular group of patients. Nevertheless, the patient and clinical characteristics were not uniform as a subgroup analysis was lacking, in addition to limited number of trials included in this meta- analysis.[56]

HFNC also has a role in situations where bag-mask ventilation after induction of anesthesia is not desirable, to minimize the risk of regurgitation and aspiration in patients susceptible like obese, pregnant, and those with increased intraabdominal pressure. This kind of induction of anesthesia is popularly termed as rapid sequence induction (RSI). There has been conflicting evidence regarding the efficacy of HFNC in preoxygenation and apneic oxygenation for RSI in patients for emergency surgeries.

In an RCT,[18] where patients were randomly assigned 1:1 to either intervention (HFNC oxygenation at 60L/min) group or control (non-rebreather mask for preoxygenation) and nasal prongs of at least 15L/min oxygen flow for (apnoeic oxygenation) group, it was concluded that use of the former for PO and ApO failed to improve lowest oxygen saturation during the first intubation attempt but lead to prolonged safe apnoea time.

In DA management a thorough PO and ApO during laryngoscopy can significantly increase the safe apnoea time and contribute to a better prognosis. Current guidelines suggest the use of HFNC for preoxygenation in anticipated DA. However, there is a lack of evidence in this regard. Recently, the PREOPTI-DAM study,[34] compared HFNC with FM for anticipated DA and observed that former did not reduce significantly the incidence of desaturation ≤94% or bag-mask ventilation during an anticipated difficult intubation. The trial was underpowered to rule out a clinically significant benefit; nevertheless, patient satisfaction was improved with HFNC.

Amongst patients scheduled for neurosurgical[47] and GI procedures,[17] HFNC was observed to be efficacious for preoxygenation and ApO; however, the latter study claimed that the subsequent fall in partial pressure of oxygen and increase in partial pressure of carbon dioxide indicates that it is not as effective as bag-mask ventilation in maintaining oxygenation and ventilation following the neuromuscular blockade.

As far as its use amongst various patient populations is concerned, in pediatric patients, it is used primarily for ApO during laryngoscopy and has been found to increase the safe apnoea time significantly.[48,49] In elderly patients, HFNC has been observed to increase safe apnea time and improve oxygenation.[50,51]

There have been only two meta-analyses that have evaluated the efficacy of HFNC for PO and ApO.[43,55] One was conducted in a specific subset of the population i.e. obese population[43] and the other in the general surgical patient population. Song et al.[55] in a meta-analysis did not observe any difference in desaturation between patients where HFNC or FM was used for preoxygenation. The shape of the oxygen-dissociation curve and patient factors may influence these findings; however, a comparison of oxygen partial pressure depicted no difference between the two techniques. This meta-analysis highlighted that HFNC does prolong safe apnea when compared to FM techniques for patients undergoing elective or emergency surgery.

2.3. HFNC for postoperative oxygenation

PPC's are a major cause of morbidity, mortality, and longer hospital stays.[43] The incidence varies between 2 to 19% in non-cardiac surgeries to as high as 40% following abdominal surgeries.[57,58] PPC's include postoperative hypoxemia, atelectasis, bronchospasm, bronchitis, respiratory infection, exacerbation of previous lung disease, pulmonary collapse due to mucus plugging of the airways, pneumothorax, aspiration pneumonitis and respiratory failure with ventilatory support >48 hours.[59] Thus, it mandates the need for aggressive clinical management based on the identification of risk factors, and implementation of specific therapeutic approaches to optimize lung function and prevent PPC's.

High-frequency nasal cannula has recently been employed for postoperative oxygenation following extubation in surgical patients.[19,59] The edges of HFNC compared with COT include delivery of a predictable FiO2, better humidification, decreased anatomical dead space, and improved patient comfort.[60] Nevertheless, failure of HFNC in patients with pulmonary complications can lead to delayed intubation causing morbidity and mortality.[61] Therefore, the safety and efficacy of HFNC are being increasingly investigated in the literature, but findings have been inconsistent.[61,62]

With an extensive literature search, we observed that most of the studies evaluating the efficacy of HFNC for postoperative oxygenation have been conducted

in obese patients and following thoracic and cardiac surgeries.[52,63–65] They concluded that the use of HFNC in comparison with COT helped to maintain the postoperative oxygenation, reduced the risk of re-intubation and the overall length of hospital stay. Routine surgical procedures like open abdominal surgeries with long surgical duration are considered to be implicated as strong risk factors for the development of postoperative hypoxemia; hence, suggesting the use of HFNC for postoperative oxygenation.

However, only a single study (OPERA trial) has evaluated the efficacy of HFNC for postoperative oxygenation following major abdominal surgeries but this study has not evaluated all blood oxygenation parameters and has also not incorporated any radiological method to rule out PPC's, and quality of recovery. In addition, the primary outcome was the PaO_2/FiO_2 ratio at one hour which was an arbitrary endpoint and standardization for different aspects of patient care varied as it was a multicentric trial.[19]

The limitations of most of these meta-analyses included small sample size, clinical heterogeneity between trials, heterogeneous patient populations, different comparators, various clinical outcomes, variations in timing and duration of HFNC treatment, different lengths of follow up, and non-feasibility of double blinding due to the nature of the intervention. The questions that have remained unanswered include the duration of its use for postoperative oxygenation, the routine use of HFNC in clinical practice, and its feasibility in resource-limited setups.

3. Strengths and Limitations

The present narrative review included all randomized controlled trials and systematic reviews pertaining to the use of HFNC in the perioperative period. It provides an in-depth understanding of the role of HFNC in diverse clinical scenarios and different patient groups in the perioperative period.

4. Limitations and Future Recommendations

The present review is a broad overview of the use of HFNC in the perioperative period and being a narrative review it could easily lead to subjective bias due to lack of quantitative analysis. Robust trials with larger sample size and systematic reviews with subgroup analysis incorporating patients' age, comorbidities, ASA status and clinical characteristics including type of procedure and interventional time point of HFNC to help establish its clinical efficacy and utility in the perioperative period over conventional modes of oxygen therapy are avenues for further research.

5. Conclusion

HFNC has an expanding role; however, indications are not absolute, with most benefits being physiologic. There is conflicting data regarding its efficacy for PO/ApO prior to intubation for elective surgical cases. However, for postoperative oxygenation, its use seems promising. Furthermore, large multicentric trials are desirable to validate these findings and their use in the emergency department needs to be explored. Dogmatic guidelines or at least institutional protocols may be formulated regarding its use in various aforementioned indications.

6. Source of Funding

None

7. Conflict of Interest

None

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