The Role of High-Flow Ventilation in the Treatment of Acute Respiratory Failure

Qoyirov A.Q.[1]	RepublicanScientific Center for Emergency Medical Care[1]
Azimov A.A.[1]	Bukhara State Medical Institute[2]
Boltayev E.B.[1,2]	Republican Scientific Center for Emergency Medical Care[1] Bukhara State Medical Institute[2]

ABSTRACT

Prevention, diagnosis and treatment of severe respiratory failure (RF) have been and remain one of the most urgent problems in medicine and resuscitation. Despite the rapid progress in life support methods and respiratory technologies, artificial lung ventilation is not able to adequately and safely prosthetize the function of external respiration. Therefore, the preservation of spontaneous breathing of the patient and the use of auxiliary non-invasive methods of respiratory support in the absence of contraindications seems to be a promising direction in the treatment of ARF , especially in the early stages. In recent years, an innovative respiratory technology has been actively introduced into clinical practice, which makes it possible to non-invasively deliver an air-oxygen mixture to a patient at a high flow rate (up to 60 liters per minute). High flow oxygen therapy (HFOT) provides not only a high flow rate, but also effective humidification and warming of the air-gas mixture with precise control of the oxygen fraction. Various studies have shown that high-flow oxygen therapy appears to be an effective and well-tolerated method of non-invasive respiratory support for respiratory failure of various origins. The purpose of this publication is to review the literature data and preliminary results of our own research on the use of high-flow oxygen therapy in various clinical situations.

Keywords: respiratory failure, respiratory support, non-invasive lung ventilation, high-flow oxygen therapy.

Introduction

In modern resuscitation and intensive care, one of the most pressing problems is severe acute respiratory failure (ARF), which requires prosthetics for the function of external respiration. According to various estimates, up to 137 cases of severe ARF per 100000 people are registered in the United States, of which 31-day mortality is 31.4% [5]. In Europe, the prevalence of severe ARF ranges from 77.6 to 88.6 cases per 100000 thousand people per year; for acute respiratory distress syndrome (ARDS), these figures range from 12–28 cases per 100000 people per year [17]. In Russia, according to various sources, an average of 15,000 cases of ARDS are registered per year, with more frequent development of severe ARF in intensive care units (ICU), depending on the nature of diseases, injuries and injuries, on average from 18 to 56% of all patients in ICU [1-3].

In the vast majority of living organisms, all metabolic processes proceed with the participation of oxygen. As the great chemist J. Berzelius noted, "Oxygen is the substance around which all terrestrial chemistry revolves." Hypoxemia and hypoxia that develop in respiratory failure (RF), regardless of their etiology, lead to the development of a cascade of severe subcellular, cellular, organ, and systemic, often irreversible, functional disorders [1, 3, 25]. Therefore, it is fundamental to prevent development, timely diagnosis and adequate treatment of DF in a very different contingent of patients, injured and wounded.

The main method of treatment of ARF and temporary prosthetics of the function of external respiration is respiratory therapy (RT), ranging from oxygen therapy and non-invasive methods of artificial lung ventilation (NIMALV) to invasive and aggressive methods of fully controlled artificial lung ventilation (ALV).

Oxygen therapy (from Latin oxygenium - "oxygen" and Greek θεραπεία - "therapy") is a method of treatment using oxygen.

Oxygen therapy is a component of respiratory therapy (RT), which includes a set of measures aimed at restoring the ventilation and gas exchange functions of the lungs. The main indications for inhalation oxygen therapy are mild forms of parenchymal, circulatory, hemic and cytotoxic hypoxia. Among the wide variety of ways to implement oxygen therapy in everyday clinical practice, humidified oxygen insufflation through nasal prongs, nasal or face masks (with or without a Venturi valve) is most commonly used. However, conventional oxygen therapy may not always be sufficient for a patient with ARF, when, due to a violation of the ventilation-perfusion relationship in the lungs, a simple increase in the oxygen fraction in the inhaled gas does not lead to an improvement in arterial oxygenation [1, 3, 25, 33, 50,59,60]. In addition, this technique has a number of limitations:

• effectiveness only in mild forms of DF;
• gas flow rate up to 15 l/min.;
• "dilution" of the oxygen-gas mixture flow with air;
• constitutional, somatic and neurological limitations of the method application;
• inefficient humidification of the gas mixture;
• inefficient heating of the gas mixture [25, 33].

According to modern concepts, in the treatment of severe ARF, it is advisable to use not only RP, but also a complex of non-respiratory and pharmacological methods both to influence various mechanisms of ARF pathogenesis, and to reduce the aggressiveness of mechanical ventilation and prevent the development of ventilator-associated lung injury (VALI) [1,2,60].

Indeed, invasive mechanical ventilation with aggressive parameters used in severe ARF, on the one hand, allows you to correct severe gas exchange disorders, on the other hand, it has a number of immediate and delayed negative effects on organs and systems: hyperinflation, barotrauma, volutrauma, atelectotrauma, biotrauma, regional ventilation disorders /perfusion, respiratory-associated tracheobronchitis and pneumonia, extrapulmonary purulent-septic complications, cardiohemodynamic disorders, etc. Therefore, in recent years, the concept of safe or gentle mechanical ventilation has been developed [1, 3]. One of the principles of this concept is the preservation and maintenance of spontaneous breathing of the patient even under conditions of invasive mechanical ventilation, which provides:

• prevention of respiratory muscle atrophy;
• improvement of regional ventilation-perfusion relations;
• decrease in the aggressiveness of the parameters of mechanical ventilation - reducing the risk of developing VALI;
• improvement of cardiohemodynamics;
• reduced need for sedation and myoplegia;
• the possibility of contact with the patient;
• preservation of the cough reflex - reducing the risk of developing ventilator-associated pneumonia (VAP);
• reduction in the duration of the RT.

These effects can be most fully realized when using NIV, which has a number of advantages:

• an alternative to tracheal intubation — minimizing the risk of damage to the upper respiratory tract (DURT);
• greater safety and comfort for the patient;
• preservation of spontaneous breathing;
• reducing the risk of developing VAP;
• less negative cardiohemodynamic and respiratory effects;
• the possibility of contact with the patient;
• lower cost of the method.

NIV allows you to effectively correct various disorders of gas exchange in the lungs, reduces the need for intubation, and enables earlier extubation. There are many NIV methods and ways to connect a respirator to the patient's respiratory tract (RT). However, with greater safety and comfort for the patient, NIV is more complex and time-consuming for the doctor, since it is necessary to continuously "adapt" the various NIV parameters to the constant changes in the patient's respiratory pattern. In addition to the undeniable advantages, NIV has a number of disadvantages:

• impossibility of application at a low level of consciousness, anatomical features of the patient;
• pain, erythema and damage to the skin of the face when using mask NIV;
• inadequate hydration and warming of the gas mixture - damage to the mucous membrane of the nasopharynx and oropharynx, upper respiratory tract (URT), especially with prolonged use;
• aerophagia, nausea, heartburn;
• individual intolerance (claustrophobia).

High-flow oxygen therapy (HFO) is a type of NIV, has undoubted advantages over traditional oxygen therapy, is more comfortable, devoid of many disadvantages of NIV, and, as research results show, can be an effective alternative to NIV in ARF of various genesis [13, 18, 24, 38, 42,60] .

Equipment

High-flow oxygen therapy is implemented by means of a high-speed gas flow generator (up to 60 liters per minute or more), a system for effective humidification and warming of the gas mixture with the possibility of step-by-step regulation of the flow rate and temperature, precise setting of the oxygen fraction, as well as a special circuit made of semi-permeable material that does not allow condensation, and original nasal or tracheostomy cannula [33, 38].

To date, equipment for high-flow oxygen therapy is represented by two companies: Fisher and Paykel (Airvo-2, Optiflow, New Zealand) and Vapotherm (High Velocity Nasal Insufflation, USA).

Mechanisms of clinical efficacy of high-flux oxygen therapy

The basis of the clinical effectiveness of HFOT is the possibility of creating a high gas flow rate (up to 60 l/min.), which provides [12, 24, 32, 34]:

• high gas flow rate, significantly exceeding the flow rate when the patient inhales, minimizes the "admixture" of room air and allows you to maintain a predetermined high oxygen fraction;
• high gas flow rate reduces resistance in the upper respiratory tract (URT) and reduces the patient's work of breathing;
• a high gas flow rate corresponds to a high gas velocity when inhaling patients with ARF (pathological neurorespiratory drive), resulting in a decrease in thoracoabdominal asynchronism, a decrease in respiratory rate (RR), and an increase in tidal volume (TV);
• high gas flow rate improves gas exchange by generating positive pressure in the hypopharynx and URT (CPAP-like effect);
• high gas flow rate improves CO2 elimination and alveolar ventilation, reduces anatomical dead space (dead space washout effect);
• positive respiratory effects of high gas flow rate are not accompanied by deterioration of cardiohemodynamics.

Indeed, it has been shown that a high gas flow rate in HFOT reduces the resistance in the nasopharynx, the URT and, thus, reduces the patient's work of breathing [6, 11,12,49,58]. Positive pressure in the URT (2–5–7 cm of water column) created by a high-velocity gas flow (CPAP like effect) was measured by R. Parke et al. [26,47,53] These authors proved the dependence of the generated positive pressure on the flow rate - its significant increase from an average of 35 l/min. In studies on healthy volunteers, N. Groves et al. revealed the dependence of the value of positive pressure generated in the upper respiratory tract during HFOT on the breathing of a patient with a closed or open mouth and a significant role of gas leakage due to a mismatch between the size of nasal cannulas and the nasal cavity of patients, as well as due to individual characteristics of the anatomy of the upper respiratory tract [14].

Adequate humidification and warming of the gas with any respiratory support (RS) method is a fundamental issue of lung protection and mechanical ventilation safety [31, 44]. Standard heat and moisture exchange disposable filters are not able to perform these tasks both with invasive ventilation and with NIV. It should be remembered that during breathing, warming and humidifying the air in the upper respiratory tract are an energy-dependent process (up to 156 cal/min), and energy consumption progressively increases with ARF [46]. Therefore, effective humidification and warming of the gas mixture under RS conditions provides:

• improvement of the function of the epithelium of the URT and alveoli;
• improvement of the functional state of all structures of the tracheobronchial tree (TBT) and lungs;
• prevention of development of tracheobronchitis and pneumonia;
• reduction of metabolic costs for heating and humidification of the gas mixture;
• reduction of volatile production of CO_2;
• comfort and good tolerability of the method.

An important condition for the functioning of the HFOT is the use of the original semi-permeable material of the respiratory circuit, which prevents the formation of condensate in it and reduces the risk of nosocomial infection [38, 45].

The above features of HFOT suggest the possibility of a more physiological prosthesis of the function of external respiration using this method.

Thus, the principal mechanism that determines the clinical effectiveness of HPE is the creation of a gas flow that significantly exceeds the inspiratory flow of the patient and the generation of positive pressure in the URT.

At the same time, it should be noted that the effectiveness of HFOT is due to the combination of all these factors. On the other hand, in different clinical situations, depending on the dominance of one or another mechanism of ARF pathogenesis, it is difficult to determine what determines the effectiveness of this method to a greater extent. Therefore, further research is needed to determine the optimal algorithm for the use of HFOT in ARF of various genesis.

Clinical efficacy of high-flow oxygen therapy in the development of RF of various origins

Traditionally, before the widespread introduction of non-invasive mask ventilation into clinical practice in the development of ARF, the main issue was the timely intubation of the trachea and the start of mechanical ventilation. In case of parenchymal ARF, the violation of the oxygenating function of the lungs is based on regional violations of ventilation / perfusion in the lungs, therefore, in this situation, an increase in the oxygen fraction in the inhaled gas with traditional low-flow oxygen therapy is ineffective.

In addition, conventional low-flow oxygen therapy has an oxygen flow rate of 10–15 L/min. (with low volume of gas flow). Whereas the rate of peak gas flow during a normal inhalation of an adult is on average 20-40 l / min. and significantly increases with the development of ARF.

As a result of this difference, during the patient's breathing, room air is added to the oxygen flow supplied in this way, and the real oxygen fraction in the gas flow decreases [12,54]. In addition, with oxygen therapy, it is impossible to adequately moisturize and warm the oxygen-air mixture. All this determines the low efficiency of traditional low-flow oxygen therapy and raises the question of the advisability of its use in the manifestation of ARF. The widespread introduction of non-invasive methods of respiratory support into clinical practice makes it possible to effectively prosthetize the function of external respiration in RF of various origins and in many situations to avoid tracheal intubation.

Despite the relative novelty of the method, HFOT has shown its effectiveness when used in a different contingent of patients with manifestations of RF of various origins. A number of studies have shown the high clinical efficacy of HFOT in the manifestation of ARF and the possibility of using this method as an alternative not only to traditional oxygen therapy, but also to non-invasive mask ventilation.

O. Roca et al. were among the first to show the clinical efficacy of HFOT in the treatment of patients with ARF. When comparing the clinical efficacy of this method with traditional oxygen therapy in patients with ARF (SatO2 < 96%), after 30 minutes of using HFOT, a significant improvement in gas exchange, external respiration, and hemodynamics was noted with greater comfort compared to humidified oxygen insufflation [34]. Research by V. Sztrymf et al. revealed a greater clinical efficacy of HFOT compared to mask NIV in patients with ARF on the background of pneumonia or sepsis: a significant decrease in RR, an increase in SpO2, greater comfort (the average duration of continuous use of HFOT averaged 26 hours) [44].

J. Rello, M. Pérez, O. Roca et al. showed the effectiveness of HFOT in ARF caused by the influenza virus strain AN1N 1 - it was possible to avoid intubation in 45% of patients (9 out of 20 observed patients). At the same time, no nosocomial pneumonia was noted during the entire period of HFOT use [30].

R. L. Parke et al. when comparing the clinical efficacy of HFOT and traditional mask oxygen therapy in 60 patients with parenchymal ARF of various genesis of mild and moderate severity, they showed a significantly lower frequency of tracheal intubation in the HFOT group (10%) compared with the mask oxygen therapy group (30%) [26]. Similar positive effects were noted in patients after lung transplantation: a decrease of up to 30% in the frequency of switching to mechanical ventilation with the use of HFOT compared with mask oxygen therapy [36].

N. Schwabbauer et al. when analyzing the short-term effects of HFOT, Venturi mask and non-invasive mask ventilation with higher oxygenation in the mask ventilation group (PaO2 = 129 ± 38) than in the HFOT group (PaO2 = 101 ± 34), they noted greater comfort when using HFOT. For continuation of treatment, nine patients chose HFOT, three patients chose a Venturi mask, and one preferred mask ventilation [40].

J. P. Frat et al. in a multicenter study of 310 patients with hypoxic ARF (PaO2 / FiO2 < 300) did not reveal a significant difference in the frequency of transfer to mechanical ventilation when using HFOT, conventional oxygen therapy and NIV. However, post-hoc analysis revealed a significant decrease in the frequency of intubations during the 28-day follow-up period, lower mortality in the ICU and 90-day mortality in the HFOT group [13].

F. Stephan et al. in a study in 830 patients after cardiac surgery (coronary bypass grafting, valve replacement, etc.), no significant differences were found in gas exchange rates, intubation rates, days without mechanical ventilation and mortality in the ICU when using non-invasive mask ventilation and HFOT. The authors showed that in 10% of patients after 24 hours of non-invasive masking, various injuries of the skin of the face took place [43].

B. Sztrymf, J. Messika et al. in a study in 38 patients with parenchymal ARF, they showed a decrease in dyspnea, heart rate, thoracoabdominal asynchronism, an improvement in pulse oximetry after 15 minutes of using HFOT, and a significant increase in PaO2/FiO2 after 1 hour of using HFOT. These authors found that persistent tachypnea, thoracoabdominal asynchronism, and hypoxemia indicate the ineffectiveness of HFOT in this clinical situation [45]. Despite the available research results, the issues of determining the optimal and effective algorithm for the use of high-flow oxygen therapy in the development of ARF remain unresolved:

- indications and contraindications for the application of the method;
- selection criteria between HFOT, mask oxygen therapy and NIV;
- criteria for the ineffectiveness of HFOT;
- ratio of cost, efficiency and convenience of the method;
- discontinuation criteria for high-flow oxygen therapy

Clinical efficacy of high-flow oxygen therapy during weaning from mechanical ventilation

A serious problem in the treatment of ARF is the stage of RS termination. Despite the improvement in the patient's condition and resolving RF, episodes of hypoxemia and (or) hypercapnia may develop at this stage of treatment, which are no less clinically significant than with the manifestation of RF. As a result, at this stage, there is often a need for reintubation and continuation of invasive mechanical ventilation. When weaning from mechanical ventilation, as a rule, non-NIVL or traditional convection oxygen therapy is used. Despite the routine use of these methods, there are currently no clear protocols for weaning from a respirator and algorithms for their use in RF of various origins, as well as criteria for timely reintubation.

A separate issue is the protocol for stopping RS and protecting the upper respiratory tract in patients with a tracheostomy cannula. This contingent of patients has a large number of respiratory excesses, complications and a high incidence of tracheobronchitis and pneumonia at the stage of weaning from the respirator, directly related to the presence of a tracheostomy tube.

Currently, a lot of data has been accumulated on the effective use of HFOT at the stage of weaning patients from the respirator and in the early post-extubation period as an alternative to traditional oxygen therapy and non-invasive mechanical ventilation.

In a large multicenter randomized study in 527 patients with ARF of various origins (mean age 51 years) using HFOT, the reintubation rate in the first 72 hours after extubation was 4.9% of cases, with 12% of cases in the group with conventional oxygen therapy. In the same study, a lower incidence of pneumonia was noted in the HFOT group compared to the oxygen therapy group (8.3 and 14.4%, respectively) [15].

Similar results were obtained in a retrospective randomized study by E. Brotfain et al. in 167 patients with ARF of various origins. Patients who received HFOT had significantly higher PaO_2/FiO_2 values compared to the oxygen therapy group, a shorter duration of RP and reintubation frequency (1 and 6, respectively), in the absence of significant differences in hemodynamic parameters and $PaCO_2$, treatment time in the ICU and mortality [9] .

In addition to the clinical advantages of HFOT over traditional mask oxygen therapy, in the early post-extubation period, this method was shown to be better tolerated: a decrease in heart rate, respiratory rate, a decrease in thoracoabdominal asynchronism, and greater comfort [37,53].

Given the novelty of the method, there are many unresolved questions regarding the most effective and safe algorithm for its use in the early post-extubation period:

• criteria for the effectiveness of the method;
• criteria for the method's inefficiency - assessment of the degree of risk of a delay in the escalation of the RS with the development as a result of the worst forecast;
• ratio of cost, efficiency and convenience of the method;
• effectiveness of the method in patients with tracheostomy cannula, low level of consciousness, concomitant pathology, etc. [39].

For a scientifically substantiated solution of these issues, further study of the clinical efficacy of HFOT in patients of this profile is required.

Clinical efficacy of high-flow oxygen therapy during aggressive manipulations on the upper respiratory tract

In modern medicine, anesthesiology and intensive care, there are many invasive and aggressive diagnostic and treatment procedures performed, including on the upper respiratory tract, nasopharynx, esophagus, etc. These procedures are accompanied by hypoventilation even in patients without RF and require the use of oxygen therapy or NIV [18, 19, 22, 41,50,52]. In patients with existing RF, especially under conditions of medical sedation, these procedures often require more active prosthetics of the function of external respiration. In routine practice, the doctor, unfortunately, does not always punctually follow the protocols for maintaining the patency of the upper respiratory tract. At the same time, there are no clear protocols for choosing and algorithms for using methods for prosthetics of the function of external respiration during various manipulations on the upper respiratory tract and short-term surgical interventions.

A number of comparative studies have shown the clinical efficacy of HFOT and its superiority compared to traditional oxygen therapy and even non-invasive mask ventilation when performing intubation, fiberoptic bronchoscopy, esophagogastroscopy, etc.

It has been shown that the use of HFOT during tracheal intubation and manipulations on the upper respiratory tract can reduce the severity of hypoxemia compared with traditional preoxygenation, which is important in patients with initial RF [22, 41,56].

A similar study revealed that HFOT outperforms traditional oxygen therapy and preoxygenation (lower incidence, duration, and severity of hypoxemia episodes) during planned or emergency tracheal intubation, especially under medical sedation [24,48].

The use of HFOT showed a better level of oxygenation during fiberoptic bronchoscopy compared with a low-flow oxygen mask with the same level of patient comfort [19,57].

However, in patients with moderate and severe ARF, NIVL was required in some cases during fibrobronchoscopy due to progressive hypoxemia. The same authors emphasize that bronchoscopy was tolerated satisfactorily in patients without RF using HFOT [41].

It can be concluded that HFOT is the method of choice for RS and significantly outperforms traditional oxygen therapy when performing aggressive manipulations on the upper respiratory tract, and allows you to safely increase the duration of the safe period of apnea and (or) hypoventilation. Currently, based on the high-velocity effects of gas flow, a number of techniques are used in the clinic: NO DESAT (nasal oxygen during efforts securing a tube), THRIVE (transnasal humidified rapid insufflation ventilatory exchange), BOD (buccal oxygen delivery), etc.

Despite the wide possibilities of modern respiratory technologies, the issues of choosing the most effective and safe RS method for performing various manipulations on the upper respiratory tract in different groups of patients remain unresolved:

• choice of a specific RS method in a specific clinical situation;

• criteria for the effectiveness of the method;

• indications for increasing the degree of activity of prosthetics of the function of external respiration;

• the ratio of price, risk and benefit.

It is necessary to continue research to determine the most effective and safe algorithm for the use of HFOT, in particular, and the choice of the RS method in general, in patients with various pathologies during aggressive manipulations on the upper respiratory tract.

Clinical efficacy of high-flow oxygen therapy in hypercapnic respiratory failure

With the development of hypercapnic RF against the background of decompensation of chronic obstructive pulmonary disease (COPD), the complex use of bronchodilators, anti-inflammatory, hormonal, antibacterial (according to indications) drugs, as a rule, allows you to control the situation and bring the patient to a compensated stable state. However, with a prolonged attack of bronchial asthma or asthmatic status, prosthetics of the function of external respiration and even tracheal intubation are often required. It should be noted that these patients during the period of exacerbation of bronchoconstriction do not tolerate insufflation of insufficiently moistened and heated oxygen-gas mixture under conditions of oxygen therapy or NIV. These factors in themselves can be the cause of the deterioration and progression of RF, the development of tracheobronchitis and even pneumonia in this group of patients.

In the treatment of patients with COPD, including during periods of exacerbations, HFOT may become an alternative method of respiratory support.

J. Bräunlich et al. We studied the clinical efficacy of HFOT in volunteers, patients with COPD and idiopathic pulmonary fibrosis. The subjects breathed through the VPO cannulas for 8 hours. In patients with COPD, an increase in tidal volume, a decrease in respiratory rate, heart rate and $PaCO_2$, a decrease in thoracoabdominal asynchronism were noted (most likely due to the physiological effects of the method described above) [8].

A case of effective use of HFOT in a patient with exacerbation of COPD is described: after 6 hours of HFOT use, respiratory acidosis, hypoxemia, dyspnea, and tachyarrhythmia were corrected [40,55]. A prospective study of the use of HFOT in exacerbations of COPD confirmed the clinical effectiveness of this method: a more significant decrease in the work of breathing, the level of PaCO2, RR, HR, and an increase in saturation were noted compared with traditional methods of non-invasive RS [23].

A prospective observational study revealed a decrease in the work of breathing, an improvement in alveolar ventilation (a significant decrease in PaCO2) and sleep quality when using HFOT in smokers with COPD without exacerbation compared with conventional oxygen therapy and NIV [6].

It can be concluded that such features of HFOT as effective humidification and warming of the gas mixture, "leaching" of CO2 from the upper respiratory tract, and a CPAP-like effect determine the clinical effectiveness of its use in hypercapnic RF.

Thus, the obtained results of the studies allow us to recommend HFOT not only as a starting method of RS in the manifestation of hypercapnic RF, but also for the rehabilitation of this group of patients [4, 7].

Further study of this method is required to determine the most effective algorithm for its use in this group of patients.

Clinical efficacy of high-flow oxygen therapy in cardiogenic respiratory failure

Acute heart failure (AHF) or decompensation of chronic heart failure (CHF) is often accompanied by the development of non-cardiogenic pulmonary edema, which requires the use of not only specific cardiotropic therapy, but also respiratory support, including invasive one. Except in cases of severe acute myocardial infarction, non-cardiogenic pulmonary edema usually develops gradually, which makes it possible to effectively use NIV.

Timely correction of hypoxemia and a decrease in the work of breathing when using NIV against the background of adequate cardiotropic therapy can improve the results of treatment of AHF and CHF.

Ease of use, comfort and clinical effectiveness of HFOT in various forms of RF made it possible to use this method in the complex treatment of RF against the background of decompensated heart failure. Thus, in patients with cardiogenic pulmonary edema, the use of HFOT improved gas exchange parameters and made it possible to avoid tracheal intubation [10,51]. It has been shown that in patients with NYHA class III CHF under HFOT, a twofold increase in flow rate (from 20 to 40 L/min) significantly reduced the work of breathing and right ventricular preload [35]. Similar results were obtained with the routine use of HFOT in patients after cardiac surgery [28].

These data substantiate the possibility of using HFOT in this group of patients. It should be noted that the advantages of HFOT over other non-invasive RS methods in the treatment of RF in patients with acute and chronic heart failure have not yet been proven.

Clinical efficacy of high-flow oxygen therapy in palliative care

When treating patients receiving palliative care (do-notintubate patients), the doctor often faces the moral and ethical problem of choosing the method of protecting the upper respiratory tract and maintaining breathing during the development of RF. This is usually a choice between traditional oxygen therapy or mask ventilation, which are not always able to effectively correct hypoxemia.

Taking into account the possibilities of HFOT to cope with RF of various origins more effectively than traditional oxygen therapy, and no less effectively than NIV, it is logical to suggest using this method of RS in this group of patients.

A number of studies have shown the possibility of HFOT to effectively and comfortably maintain gas exchange, reduce the work of breathing in the development of RF, and improve the quality of life in different groups of patients in palliative care. Taking into account the available data, a number of authors substantiate the possibility of using HFOT as an alternative to NIV in palliative medicine [19, 29].

A number of authors have shown the effectiveness of HFOT in newborns and children with the development of parenchymal ARF and in the early post-extubation period [16, 21].

Taking into account the available data, it can be assumed that HFOT can be effectively used in outpatient practice and during the transportation of patients.

Choice of High-Flow Oxygen Therapy Parameters

As follows from the principle of operation of modern high-flow oxygen therapy devices described above, the main adjustable parameters of this method of respiratory support are:

• gas flow rate (from 10 to 60 l/min.);

• FiO2 (21–100%);

• temperature of the air-gas mixture (from 31 to 37 °C).

At present, there is no unequivocal opinion regarding the optimal algorithm for selecting primary HFOT settings and their subsequent correction in patients with RF of various origins. Most authors agree on the need to start using HFOT only after reaching an air-gas mixture temperature of 37°C. Similar to traditional RS, it is advisable to start HFOT with a low oxygen fraction (0.3–0.4) with a gradual increase in it with persistent hypoxemia, despite the optimization of other parameters of the respiratory pattern.

At present, there is no unequivocal opinion on the choice of the starting gas flow rate. Depending on the form and severity of RF, different authors propose an escalation or de-escalation method for adjusting the flow rate. O. Roca et al. conducted an analysis of currently existing recommendations on the starting parameters of HFOT (see table) [19]:

• the beginning of HFOT after reaching the temperature in the circuit of 35–37 °C;

• FiO2 - sufficient to provide adequate PaO2 and SatO2;

• starting flow rate 30–40 l/min.;

• gradual increase in flow rate;

• gradual increase in FiO2.

Currently, there are no clear recommendations on the termination of HFOT. The general algorithms for weaning from HFOT are similar to the basic principles for reducing the RS:

• decrease in FiO2 under conditions of complex monitoring of the oxygen budget;

• Gradual decrease in gas flow rate by 5 l/min. every 6-8 hours;

• transition to oxygen therapy at a gas flow rate of less than 20 l / min. and FiO2 less than 0.5 with adequate gas exchange rates;

• Periodic renewal of HFOT (sessions) is often necessary during the weaning period.

Thus, to date, there is not enough convincing data to suggest clear scientifically based protocols for setting the primary parameters of HFOT and their subsequent correction in the development of RF of various genesis.

This applies equally to the termination algorithm HFOT. When weaning from HFOT, it is advisable to focus on the already formed protocols for reducing respiratory support. That is, the oxygen fraction should first be reduced, followed by a gradual decrease in the flow rate to 15–20 l/min. After that, in the absence of signs of an increase in RF, it is possible to transfer the patient to humidified oxygen insufflation, if appropriate.

It can be concluded that in order to scientifically substantiate and develop the most effective algorithms for the use of malware in various clinical situations, it is necessary to continue well-organized research.

Contraindications for High Flow Oxygen Therapy

During the use of HFOT, no significant adverse effects and complications have been described. Given the ease of application of the method, friendly interface, this is no less due to effective humidification and heating of the gas mixture.

The only reported side effect of HFOT was the development of respiratory acidosis in patients with COPD when using a high fraction of oxygen due to a decrease in respiratory rate and hypoventilation [4,60]

Conclusion

An analysis of the literature data on the use of HFOT in various clinical situations shows that this innovative RP method is a more effective alternative to traditional oxygen therapy and often turns out to be no less effective and more comfortable than NIV.

At present, the following provisions can be formulated regarding the methodology and clinical effectiveness of HFOT.

1. The clinical effectiveness of HFOT is based on the CPAP effect, a decrease in the work of breathing, adequate humidification and warming of the gas mixture.

2. HFOT provides greater comfort and better tolerance due to the presence of the original nasal or tracheostomy cannula, adequate temperature and humidity of the gas mixture.

3. HFOT has a user-friendly interface and wide options for adjusting parameters.

4. The original material of the breathing circuit prevents the accumulation of condensate in it and reduces the risk of secondary infection.

The results of clinical trials available to date suggest a great potential for the widespread introduction of HFOT into clinical practice in the treatment of various diseases accompanied by the development of RF.

However, a number of unresolved issues remain.

1. Principles for choosing the starting parameters of HFOT in different clinical situations.

2. Principles of subsequent correction of HFOT parameters in different clinical situations.

3. Criteria for choosing HFOT or NIV in different clinical situations.

4. Indications for intubation in the absence of the effect of HFOT in different clinical situations.

5. Criteria for identifying patients with obviously low efficiency of HFOT.

6. Algorithms for the use of HFOT in patients with tracheostomy.

7. Algorithms for terminating HFOT in different clinical situations.

Currently, the accumulated clinical experience in the use of HFOT does not allow us to give clear and unambiguous answers to these questions.

It is necessary to continue studying the clinical effectiveness of HFOT for scientific substantiation, development and implementation of optimal algorithms for its use in patients with RF of various origins.

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