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Early Diagnosis of Respiratory Disease in Light of COVID-19 Infection and Use of Oxygen Concentrators and CPAP Devices for the Treatment of Respiratory Failure

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Abstract

The need for early diagnosis of respiratory diseases, especially in the context of the COVID-19 coronavirus infection pandemic, by means of pulse oximetry screening and monitoring has been substantiated. The expediency of using portable pulse oximeters by therapists and general practitioners is shown. The main respiratory diseases accompanied by respiratory failure, which can be promptly detected by pulse oximetry, are chronic obstructive pulmonary disease and obstructive sleep apnea-hypopnea syndrome. Early detection of these diseases is an urgent task due to the low severity of symptoms of these diseases in the early stages and, as a consequence, the prevalence of late diagnosis. Pulse oximetry to detect coronavirus infection COVID-19 deserves special attention, since this infection is also accompanied by respiratory failure. The use of oxygen concentrators and CPAP devices for the treatment of respiratory failure has been argued. The effectiveness of the appointment of long-term oxygen therapy using oxygen concentrators in patients with chronic obstructive pulmonary disease, CPAP therapy using automatic CPAP devices in patients with obstructive sleep apnea-hypopnea syndrome with mandatory pulse oximetry monitoring has been confirmed. A retrospective analysis of 120 cases of treatment of moderate and severe COVID-19 infection complicated by the development of pneumonia was carried out. The efficiency of using oxygen concentrators to supply patients with oxygen at a flow rate of up to 5 l / min has been proven. It was found that no more than 10% of patients needed an oxygen flow at a rate of more than 5 l/min. At the same time, the possibility of using CPAP devices for non-invasive ventilation of the lungs using full-face masks has been shown. The expediency of using oxygen concentrators and CPAP devices for the rehabilitation of patients who have undergone COVID-19 was noted.

1. Introduction

In connection with the increase in the prevalence of respiratory diseases in the Republic of Belarus, there is an obvious need to ensure early detection, treatment and prevention of these diseases, especially in the context of the COVID-19 coronavirus infection pandemic caused by the SARS-CoV-2 coronavirus. Special attention should be

paid to the issue of technical support for diagnostics and respiratory support for patients with COVID-19, since this infection primarily affects the lungs and can be complicated by pneumonia or respiratory failure with the risk of death. At the same time, during the COVID-19 epidemic, one should not underestimate the danger of traditional respiratory diseases, since patients prefer to visit medical institutions less in order to minimize the risk of coronavirus infection. And taking into account the mild symptoms in the early stages and the slow development of diseases such as chronic obstructive pulmonary disease (COPD) and obstructive sleep apnea-hypopnea syndrome (OSAH), the problem of their early diagnosis is very important. COPD is inflammation and narrowing of the small airways that leads to chronic cough, mucus production, and progressive shortness of breath (respiratory depression).failure) and fatigue.

OSAG is a periodic cessation of breathing during sleep due to the collapse of the walls of the airways at the level of the pharynx, which leads to snoring, daytime sleepiness, fatigue, and metabolic disorders. Patients often do not pay due attention to these manifestations of the disease for a long time. As a result, late detection and late treatment lead to the prevalence of more severe degrees of these diseases and, as a result, to disability, early disability and mortality. Every fourth COPD patient becomes disabled in ten years. It should be noted a large number of patients of working age, while, for example, COPD is considered a disease of the elderly.

Respiratory failure is the leading cause of death in patients with COPD (38%). Respiratory failure syndrome is characterized by the inability of the lungs to maintain the gas composition of arterial blood in the norm (partial tension of arterial blood oxygen (PaO_2) - not less than 60 mm Hg, partial tension of carbon dioxide ($PaCO_2$) - not more than 45 mm Hg). Respiratory failure is also accompanied by such interstitial lung diseases as bronchial asthma, OSAS, etc.

2. Experimental Procedure

2.1. Respiratory Failure Diagnosis

One of the most practical methods for diagnosing respiratory failure is the non-invasive measurement of the saturation (saturation) of arterial hemoglobin with oxygen (SpO_2) using pulse oximetry. This is due to the correlation between SpO_2 and PaO_2. The value of PaO_2 should normally be in the range of 80–100 mm Hg. Art. This range corresponds to the SpO_2 normal range of 96-100%. Currently, the SpO_2 value is determined using a portable pulse oximeter, usually mounted on a finger (Fig. 1).

Figure (1). Pulse oximeter “Oxymed”.

A pulse oximeter consists of a sensor that transmits red and infrared radiation through the finger and determines the amount of absorbed radiation of each type, depending on the degree of oxygenation of hemoglobin in the tissues, as well as a display, which, in turn, displays the values of saturation, pulse rate and pulse curve. Thus, in an average of 5–20 s, a pulse oximeter allows determining the SpO_2 value and establishing the presence of respiratory failure syndrome in a patient. If necessary, it is possible to carry out night / day pulse oximetry monitoring with recording the facts of a decrease in saturation (desaturation) and their duration.

Oxygen therapy technique: To date, the most reasonable method of therapy for respiratory failure is the use of oxygen with a volume fraction of at least 90%. The goal of oxygen therapy is to maintain SpO_2> 90%, which corresponds to PaO_2> 60 mm Hg. Moreover, in patients with chronic hypoxemia, oxygen should be used for a long time. It is long-term oxygen therapy that seems to be the only effective method of treating chronic respiratory failure and increases survival of patients with COPD, prolonging their life by six to seven years [1]. In addition to COPD, long-term oxygen therapy can be prescribed for the following diseases:

- Severe course of coronavirus infection COVID-19.
- Allergic rhinitis caused by an outside source.
- Fibrosis of the lungs for unknown reasons.
- Pneumofibrosis following respiratory infections or TB.
- Diseases of the interstitium of the lungs, such as sarcoidosis and histiocytosis, are also included.
- kyphoscoliosis.
- CF, or cystic fibrosis.
- Asthma of the bronch.
- Connective tissue injury and lung damage.
- Proteinosis of the lungs (a storage condition).
- Hypertension of the lungs.
- Syndromes of respiratory failure can occur in a variety of medical contexts, such as when heart failure is present.

There are currently no well-established absolute contraindications to oxygen therapy. Patients with chronic hypercapnia should be given an oxygen dosage that keeps their arterial oxygen saturation (SpO_2) between 90% and 92% and whose PaO_2 is kept within 60-65 mm Hg. Art. Patients having radiation therapy and amiodarone may experience diffuse lung damage (bilateral pulmonary infiltrates, unproductive cough, dyspnea, reduced lung compliance) and may benefit from oxygen therapy.

Table (1). Indications for long-term oxygen therapy

PaO_2, mm Hg Art.	SpO_2, %	Indications	Special conditions
<55	<88	Absolute	No
55–59	89	Relative under special conditions	Pulmonary heart disease, edema, polycethemia (H> 55%)
60	90	No indication except under special conditions	Desaturation during exercise. Desaturation during sleep. Lung disease with severe dyspnea ameliorated by O2

At present, when carrying out long-term oxygen therapy, the use of oxygen concentrators as a source of oxygen seems to be the most optimal. Oxygen concentrators provide an oxygen-containing mixture with a volume fraction of oxygen up to 95% directly from the ambient air [1]. Oxygen delivery to the patient can be achieved through a low-flow nasal cannula, a high-flow moisturized face mask, a simple face mask, a reservoir mask, a venturi mask, etc. In the case of long-term oxygen therapy, the use of a low-flow nasal cannula is most effective (Fig. 2).

Figure (2). The use of a low-flow nasal cannula with an oxygen concentrator "Oxymed".

The use of oxygen requires compliance with the regimen and dosage (Table 2). A prerequisite for oxygen therapy is pulse oximetric monitoring of SpO_2 [1].

Table (2). Modes of long-term oxygen therapy by means of a nasal cannula.

PaO_2, mm Hg Art. without oxygen therapy	SpO_2,% without oxygen therapy	Oxygen therapy regimen using a nasal cannula	
		Oxygen flow rate 90%, l / min	Duration, h
55–60	88–90	1	at least 15 hours a day: 8 hours at night; 2 sessions of 3.5 hours in the daytime with breaks no more than 2 hours in a row
50–54	85–87	2	
45–49	81–84	3	
40–44	75–80	4–5	

It should be noted that oxygen therapy can be carried out in a portable pressure chamber, which provides a slight overpressure of up to 1.15 ATA. In this case, it is also advisable to use an oxygen concentrator as a source of oxygen (Fig. 3), which, through a nasal cannula, delivers an oxygen-containing mixture to a patient inside a portable pressure chamber. It is possible to connect an oxygen concentrator to the pressure chamber body and create an increased oxygen concentration inside it up to 35%. In this case, a nasal cannula is not required.

Figure (3). The use of a portable pressure chamber with an oxygen concentrator "Oxymed".

A session of normoxic barotherapy includes compression for 5–6 minutes, exposure for 40 minutes, and decompression for 5–10 minutes. The course of treatment includes 7-10 sessions, which are carried out daily. If necessary, additional courses of treatment are carried out 2-3 times a year.

2.2. CPAP Therapy Technique

If the patient, according to the results of night / day pulse oximetry monitoring, has a decrease in SpO_2 only during sleep, this may indicate obstructive sleep apnea syndrome (OSAS). This syndrome consists in a periodic collapse of the upper respiratory tract at the level of the pharynx, accompanied by snoring, and, as a consequence, the cessation of pulmonary ventilation with persisting respiratory efforts. OSAS is characterized by gross sleep fragmentation, decreased blood oxygen levels, and excessive daytime sleepiness. With the complete closure of the airways and the cessation of the air flow for 10 s or more and a decrease in SpO_2 by 3% or more, one speaks of obstructive apnea. In the case of incomplete collapse of the airways, with a decrease in the respiratory flow by at least 50% and at least 10 s with a decrease in SpO_2 by 3% or more, one speaks of obstructive hypopnea. A distinction must be made between obstructive sleep apnea and central sleep apnea. During central sleep apnea, there is a decrease in function or arrest of the respiratory center, respiratory effort ceases. The airways remain open at the same time.

The Apnea-Hypopnea Index (AHI) measures the severity of obstructive sleep apnea and represents the frequency of apnea and hypopnea attacks per hour of sleep. Mild degree - 6-14 apnea-hypopnea in one hour. The average degree is 15–29. Severe degree - 30 and above.

The most effective non-surgical treatment for obstructive sleep apnea is CPAP (Constant Positive Airway Pressure) therapy. The idea behind CPAP therapy is to create positive air pressure in the airways. Positive air pressure keeps the patient's airways open during sleep. For CPAP therapy, specialized equipment is used - SAPAP devices (Fig. 4). They independently determine the state of apnea-hypopnea and automatically adapt the level of therapeutic pressure based on the needs of the patient, thereby adjusting to his breathing rhythm.

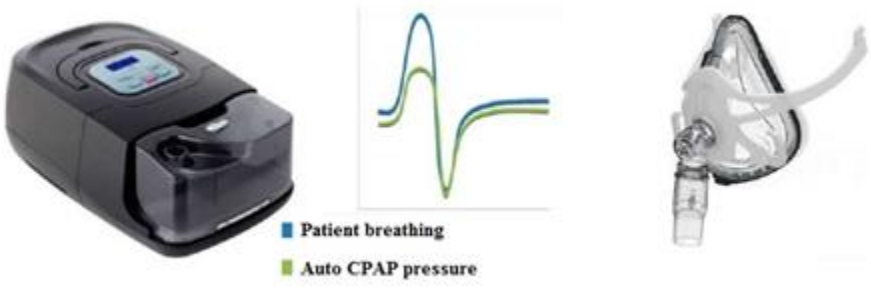

Figure (4). BMC RESmart AUTO CPAP.

At the same time, it should be noted the possibility of using CPAP devices for the treatment of respiratory failure along with non-invasive mechanical ventilation (NIV) devices, including for patients with severe coronavirus infection. In this case, the following advantages of CPAP therapy should be highlighted: it is carried out non-invasively with the help of face masks; well tolerated by patients; ease of use and affordable cost of CPAP equipment; a large variety of CPAP masks to ensure patient comfort and take into account his individual characteristics. Moreover, in the conditions of a shortage of specialized masks for NIV and CPAP masks, a successful experience was obtained in the use of no less comfortable masks for scuba diving (snorkeling) after appropriate refinement of their design using 3D printing.

3. Results and Discussion

On the basis of the clinic of the State Institution "Republican Scientific and Practical Center of Pulmonology and Phthisiology", a retrospective analysis of 120 cases of treatment of moderate and severe COVID-19 infection complicated by the development of pneumonia was carried out.

Pulse oximetry monitoring of SpO_2, as well as monitoring of respiratory rate, blood pressure, heart rate, body temperature, level of consciousness, oxygenation index, urine output in patients receiving oxygen therapy, was carried out at least 6 hours later, in patients not receiving oxygen therapy, - every 12 hours.

At SpO_2 more than 95% and a respiration rate of less than 24 per minute, oxygen therapy was not prescribed, dynamic observation was carried out. At a SpO_2 value of 91–95%, a rotation to the prone position was performed; in the absence of an effect, oxygen was supplied to the prone position for 1 h (SpO_2 <95%) at a flow rate of 1–5 L / min. With an initial SpO_2 of 85–90%, the algorithm of action included a pron-position with an oxygen supply at a flow rate of more than 5 L / min; if there was no effect within 1 hour, a resuscitation specialist was called.

Oxygen supply with a flow of up to 5 l / min was carried out including using oxygen concentrators "Oksimed", model F7-5, more than 5 l / min - through a stationary oxygen system. When comparing the method of oxygen delivery with a flow of up to 5 l / min. Comparable effectiveness was noted. No more than 10% of patients required an increase in flow. Six patients (5%) had persistent desaturation (SpO_2 <85%), which required transfer to the intensive care unit.

4. Conclusions

Timely detection of diseases in order to prevent their progression and increase the effectiveness of treatment is a priority of medicine. Most diseases are easier to prevent than to treat, and early treatment is usually less costly and more effective.

Pulse oximetric screening by physicians and general practitioners can detect respiratory failure, characterized by a decrease in SpO_2 below 94%, at an early stage to establish the disease causing it (COVID-19, COPD, OSAG, etc.), and to prescribe the necessary therapy in a timely manner. Oxygen concentrators are offered as technical support for oxygen therapy of respiratory failure, since they do not require refueling and can be successfully used both in hospital and at home. If obstructive sleep apnea syndrome is detected based on the results of night / day pulse oximetry monitoring, automatic CPAP devices are used to maintain the optimal therapeutic pressure in the patient's airways during sleep.

In addition, CPAP devices, along with oxygen concentrators, can be used for the treatment of respiratory failure in patients with severe coronavirus infection as an easier-to-use and affordable alternative to NIV devices. At the same time, the use of oxygen and CPAP therapy is recommended for the rehabilitation of patients with COVID-19. Oxygen therapy and CPAP therapy are carried out in accordance with the methods approved by the Ministry of Health of the Republic of Belarus.

The above equipment has undergone clinical trials, is registered with the Ministry of Health of the Republic of Belarus as medical equipment, is included in the register of measuring instruments of the State Standard and is approved for use.

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