Modes of Non-invasive Respiratory Support Devices and their Significance in the Treatment of COVID-19

Sambardhan Dabadi[1], Raju Raj Dhungel[1], Saugat Acharya[1], Pratik Poudel[2], Anik Jha[2], Jitesh Shrestha[3]

[1]*Department of Biomedical Engineering, Annapurna Neurological Institute and Allied Sciences, Maitighar, Kathmandu*

[2]*Department of Internal Medicine, Annapurna Neurological Institute and Allied Sciences, Maitighar, Kathmandu*

[3]*Department of Anaesthesia, Annapurna Neurological Institute and Allied Sciences, Maitighar, Kathmandu*

CORRESPONDENCE

Er. Sambardhan Dabadi
Department of Biomedical Engineering
Annapurna Neurological Institute and Allied Sciences
Email : Sambardhan51@gmail.com

ARTICLE INFO
Article History
Submitted: 30 June, 2021
Accepted: 22 July, 2021
Published: 8 August, 2021

Source of support: None
Conflict of Interest: None

ABSTRACT

Introduction: The Novel Coronavirus pandemic (COVID-19) is threatening people all over the world. Each country worldwide has been affected by COVID-19 and over 300 million people have lost their lives. Acute Respiratory Failure (ARF) is the main complication for COVID-19 patients.Various oxygen therapy devices such as oxygen concentrator, high flow nasal cannula, positive airway devices like continuous positive airway pressure (CPAP), bilevel positive airway pressure (BiPAP) have much helped the patients to recover from the ARF. The use of these technology made it possible to avoid the severity of the disease and, consequently, the need for invasive ventilation and an intensive care unit (ICU).Different ways and techniques of using such devices and their significance have been mentioned in this study.

Keywords: Acute respiratory failure; BiPAP; COVID-19; CPAP; Non-invasive ventilation.

INTRODUCTION

Non-invasive ventilation (NIV) refers to the use of a breathing support system with a face mask, nasal prongs, or helmets for a patient who is not able to breathe on their own. It has been termed non-invasive as there is no use of the endotracheal tube, a tube that is inserted into the windpipe via the mouth.[1] The hermetically sealed mask is used to create a high pressure around the respiratory tract enabling the mechanism of respiration. Various devices are in use for NIV such as continuous positive airway pressure (CPAP), Bi-level positive airway pressure (Bi-PAP), high flow nasal cannula (HFNC), oxygen cylinders and concentrators. In past, the various modes of NIV were popular among patients with the chronic obstructive pulmonary disorder (COPD), asthma, sleep apnoea, and in the weaning phase of patients from invasive ventilation in a hospital setting.[2]

However, the rise of COVID-19 from 2019-2021, which has affected more than one hundred and eighty million population, causing more than three million deaths worldwide has increased the use of the NIV.[3] The major symptoms of COVID-19 are fever, tiredness, dry cough, and breathing difficulties. But among these, respiratory distress and shortness of breath are more severe and acute. Severe respiratory distress causes a decrease in tidal volume and oxygen saturation drop, causing discomfort in patients.[4] Therefore, the use of respiratory support devices in COVID-19 patients has been widely used as a primary treatment procedure.

MODES of NIV

A. Oxygen Therapy Devices

Oxygen is the most required gas for human survival. Present abundant in the atmosphere, a healthy person can easily inspire oxygen, while patients with respiratory failure or shortness of breath cannot inspire the required amount of oxygen. So, there comes the need for the use of oxygen therapy devices. The most common and widely used method of the NIV is through the nasal prongs and a face mask. These devices directly supply pure oxygen to the respiratory tract allowing the intake of oxygen for patient with minimal effort. Different types of direct oxygen gas supply systems like central oxygen lines and oxygen stored in a tank are commonly used. However, the shortage of oxygen gas in the cylinders caused the use of oxygen concentrators.

An oxygen concentrator takes in air from the room, pressurizes that, and purifies to separate oxygen from the room atmosphere. The concentrator can offer upto 10L/min of oxygen depending upon its capacity. This device has been well used to cure COVID-19 patients with mild and moderate symptoms.[5] The use of Y-connector has been extensively done to increase the output of the concentrator using two concentrators at a time.

In severe respiratory failure, where the flow provided by concentrator (5-10 L/min) and a central oxygen line or cylinders (15L/min) is not enough for the patients, a high flow nasal cannula is the available device for treatment. HFNC is actively used in different hospitals to treat COVID-19 patients suffering from respiratory failure as a method of delivering high levels of oxygen. The HFNC is made up of an air-oxygen mixer, a humidifier, a breathing tube and a nasal cannula. This device intakes the oxygen from a cylinder or central line at the rate of up to 15L/min mixes it with the compressed air using a blender and can deliver upto 60 to 80L/min depending upon the type and model of the device.[6] Use of HFNC has been able to decrease the mortality in patients with hypoxemia respiratory failure and reduced the risk of later invasive ventilation and need of intensive care unit (ICU) admission. The oxygen concentrators are equally important in providing the necessary support to post-covid patients.[7]

B. Continuous Positive Airway Pressure (CPAP)

CPAP is a type of positive airway pressure device that is used to deliver a set pressure to the patient which is maintained during the respiratory cycle. CPAP is a well-known device for pressure-controlled ventilation and breathing assistance in various cases such as sleep apnoea, COPD, and acute hypoxemic respiratory failure (AHRS).[8]

The CPAP generates a high pressure of compressed air, which in combination with central oxygen supply can be delivered to the patient's lungs through an airtight face mask. The high pressure created during each cycle of respiration helps the alveoli to remain open during the expiratory phase, which is very helpful for oxygenation and easy breathing. Usually, CPAP can be operated in two modes. One of them is CPAP mode, where the machine emits a constant stream of air at the set pressure level. The other mode is AutoPAP, where the machine auto-adjusts the pressure values ranging from maximum to minimum level set by the user based on the breathing pattern of the patient.

CPAP in the case of COVID patients is used to treat hypoxia and reduce the work of breathing so that the diaphragm does not get fatigued due to shortness of breath and increased rate of respiration. This machine is equally important while extubating the patient who still requires positive pressure but does not need invasive ventilation.[9]

Use of CPAP in covid patients helps to reduce the chances of respiratory failure due to fatigued diaphragm, reduce the respiratory distress and respiratory rates.

C. Bilevel Positive airway pressure (BiPAP):

BiPAP is a similar kind of device as the CPAP and is often used in COVID-19 patient in critical care setting. This provides two different pressure levels during the inspiration and expiration phases of the breathing. As this provides two pressure levels this is termed as BiPAP. Unlike in CPAP, the user has to set up the inspiratory pressure (IPAP) and expiratory pressure (EPAP) in BiPAP. BiPAP has a wide range of applications in conditions like respiratory failure like pneumonia, COPD, and pulmonary edema.[10]

BiPAP can be operated in three different modes, namely, spontaneous (S), timed (T), and spontaneous/timed (S/T) mode. In S mode, the device will change to IPAP (higher pressure) whenever breath is initiated by the patient and shifts to EPAP (lower pressure) during expiration. In T mode, there will be a cyclic change in IPAP and EPAP values to generate the rhythmic breathing pattern. While S/T mode is the combination of S mode and T mode. The device sets to IPAP for the patient's effort to breathe and also the rate of breathing (bpm) is maintained by keeping a fixed time to alter between IPAP and EPAP.

The following figure explains the change in positive end-expiratory pressure (PEEP) values in alveoli while using the various modes of ventilation.

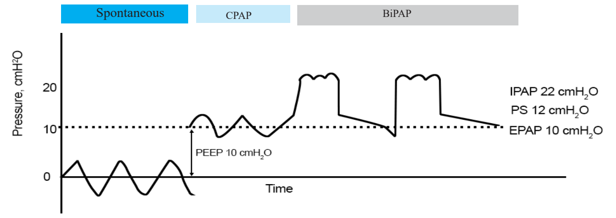

Figure 1: Representation of respiratory pattern and changes of PEEP in different ventilation modes.[11]

COMPARATIVE CHART

Device	Price	Weight	Usability	Merit	Use in COVID -19 patients
Oxygen Concentra-tor	Moderate	Heavy (15-25kg)	Home, hospital	Improves the survival rate	Immediate increase in saturation level
HFNC	HIGH	Light portable	Hospital	Can be used in severe hypoxia	
CPAP	Low	Light	Home, Hospital, ambulance	Supports respiratory muscle prevents fa-tigued muscles	Moderately affected patient with increase respiration rate and long oxygen support
BiPAP	Moderate	Light	Home, Hospital, ambulance	Provides emergency support to patients with moderate to severe	Moderately and severely affected patients can use
Ventilators (invasive)	HIGH	Portable	Hospital	Full rest to respiratory muscle	Severely affected

DISCUSSION

In this paper, various non-invasive breathing support aid is discussed and their use in the patient suffering from respiratory distress and acute respiratory failure due to COVID-19 are reviewed and analyzed. Non-invasive ventilation is the first step in treating a patient with COPD and ARF that has also been widely used in patients with COVID-19. Various studies have shown that patients who received respiratory support at the right time had a higher survival and recovery rate than those without access to such facilities. Early and timely exposure to such facility led to a reduced rate of invasive ventilation while those who presented to the hospital in late-stage and lacked proper oxygenation therapy had to be intubated in most of the cases.[11,12] In a study done by Frat et al. the sequential use of NIV and HFNC in alternating sessions in patients with PaO2/FiO2 <300 had shown better improvement and though PaO2 were so low they did not require invasive ventilation.[13] Similar study during SARS pandemic in 2003, the study in patients with ARF and mean PaO2/ FiO2 of 137, patients were treated with BiPAP, suggested that 70% of the patients did not require invasive ventilation and showed significant improvement of symptoms. These data suggest that NIV ventilation can be a crucial factor in improving the symptoms of ARF and the use of such devices in due time can prevent the risk of further damage, which can be used to avoid the need for invasive ventilation.[14] In our experience the patients who had early admission and early availability of oxygen therapy, and another mode of NIV did not show any severe complications and the need for ICU was minimal than in patients who had admitted in a late stage of infection and without respiratory support devices.

CONCLUSION

The COVID-19 pandemic is still underway and is causing a great deal of chaos among people. Acute and severe respiratory failure and pneumonia associated with COVID-19 are the leading causes of death. However, the use of oxygen therapy devices during the initial phase of hypoxia and proper use of CPAP, BiPAP, and HFNC can significantly improve the condition of the patient leading to minimized risk, the need for invasive ventilation, and ICU due to severe symptoms.

REFERENCE

1. Cummings JJ, Polin RA. Noninvasive respiratory support. Pediatrics. 2016 Jan 1;137(1).

2. Benditt JO. Novel uses of noninvasive ventilation. In: Respiratory Care. Respir Care; 2009. p. 212–9.

3. Wu YC, Chen CS, Chan YJ. The outbreak of COVID-19: An overview. Vol. 83, Journal of the Chinese Medical Association. Wolters Kluwer Health; 2020. p. 217–20.

4. Ñamendys-Silva SA. Respiratory support for patients with COVID-19 infection. Vol. 8, The Lancet Respiratory Medicine. Lancet Publishing Group; 2020. p. e18.

5. Hui DS, Chow BK, Lo T, Ng SS, Ko FW, Gin T, et al. Exhaled air dispersion during non-invasive ventilation via helmets and a total facemask. Chest. 2015 May 1;147(5):1336–43.

6. Okuda M, Kashio M, Tanaka N, Matsumoto T, Ishihara S, Nozoe T, et al. Nasal high-flow oxygen therapy system for improving sleep-related hypoventilation in chronic obstructive pulmonary disease: A case

report. Journal of Medical Case Reports. 2014;8(1).

7. Nishimura M. High-flow nasal cannula oxygen therapy in adults: Physiological benefits, indication, clinical benefits, and adverse effects. Respiratory Care. 2016 Apr 1;61(4):529–41.

8. Kakkar RK. Continuous Positive Airway Pressure. In: Encyclopedia of Sleep. Elsevier Inc.; 2013. p. 490–9.

9. Gupta S, Donn SM. Continuous positive airway pressure: Physiology and comparison of devices. Vol. 21, Seminars in Fetal and Neonatal Medicine. W.B. Saunders Ltd; 2016. p. 204–11.

10. Davidson TM. CPAP, APAP, and BIPAP. In: Sleep Apnea and Snoring. Elsevier; 2009. p. 60–8.

11. Mas A, Masip J. Noninvasive ventilation in acute respiratory failure. International Journal of COPD. 2014;9:837–52.

12. Islam MM, Ullah SMA, Mahmud S, Raju SMTU. Breathing Aid Devices to Support Novel Coronavirus (COVID-19) Infected Patients. SN Computer Science. 2020;1(5):1–8.

13. Frat JP, Brugiere B, Ragot S, Chatellier D, Veinstein A, Goudet V, et al. Sequential application of oxygen therapy via high-flow nasal cannula and noninvasive ventilation in acute respiratory failure: An observational pilot study. Respiratory Care. 2015 Feb 1;60(2):170–8.

14. Cheung TMT, Yam LYC, So LKY, Lau ACW, Poon E, Kong BMH, et al. Effectiveness of noninvasive positive pressure ventilation in the treatment of acute respiratory failure in severe acute respiratory syndrome. Chest. 2004 Sep 1;126(3):845–50.