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"Oxygen Therapy And Its Relevance In Ongoing Covid 19 Pandemic"

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Abstract: It was in 1850s that scientists realised that Earth is a closed system where even Oxygen and Carbon dioxide are exchanged between animals and plants for their co-existence and survival. Humans need Oxygen to be used for cellular respiration. It is the process by which human cells break down sugar to produce energy. This energy is stored to fuel life. This can be easily compared to a burning wood which uses oxygen to produce heat and carbon dioxide as waste. The current Covid pandemic made us realise the importance of oxygen. Corona virus hampers the process of absorption of oxygen by lungs by damaging alveolar-capillary membranes. In absence of an effective therapy to counter the virus, the management of patient is essentially symptomatic, basics of which revolves around oxygen therapy. The mere size of the pandemic has exhausted all medical facilities and many patients were treated at home, the knowledge of oxygen therapy for healthcare personnels and common people has become pertinent. Here we have tried to explain the basics about oxygen therapy in relation to Covid 19 pandemic , which is not static and expected change with time.

Key words: Oxygen therapy, Covid 19 pandemic, Corona virus infection, Oxygen pathophisiology, Pulse oximetery.

Introduction:

Oxygen, in its most stable diatomic form as Dioxygen (O_2) is a colourless and odourless gas. It constitutes around 20.95% in the atmosphere and almost half of the earth's crust in form of oxides.[1]

Oxygen has been in use for life support as in space suits, submarines, underwater divers; and for industrial use like smelting of iron ore into steel (this alone uses 55% of total oxygen used for industrial purposes), in chemical industries for manufacturing antifreeze and polyester, for metal cutting and welding etc. But the most important use which has been a matter of concern in recent times is its medical use.

The oxygen movement from the pulmonary capillary to the mitochondria within cells for production of energy crucial to sustain life is done by Respiratory and cardiovascular systems within cells for production of energy crucial to sustain life. Sever acute respiratory syndrome Corona virus-2 (SARS-CoV-2) is the third coronavirus that has caused severe disease in humans to spread globally in the past two decades.[2]

The virus attacks the nasal, bronchial epithelial cells and pneumocytes leading to endothelial barrier disruption, dysfunctional alveolar-capillary oxygen transmission, and impaired oxygen diffusion capacity.[3] In severe infection fulminant activation of coagulation and consumption of clotting factors occur leading to thrombotic complications. A dysregulated immune response may finally lead to multiple organ failures and death. More than 75% of patients hospitalized with COVID-19 require supplemental oxygen therapy as a support to recovery.[4]

The ongoing pandemic of Covid -19 infection with its several waves of disease and deaths worldwide has put the healthcare infrastructures in almost all the countries under tremendous pressure. On of the most needed logistic support, scarcity of which escalated the mortality rates in COVID-19 patients is liquid medical oxygen. Liquid medical oxygen is the most common form in which medical oxygen is supplied to healthcare facilities. Herein we would try to know about production, use and role of oxygen therapy in Covid-19 patients.

Hospitals have wall outlets supplied from liquid O_2 storage tanks (-183 degrees C). This solution requires advanced cryogenic technology with storage as well as transportation of liquid Oxygen. Oxygen is supplied from pressurized Oxygen cylinders (200 bars) sometimes stored to supply wall outlets but more often moved from bed to bed as per need.[5]

Methods of production of medical grade liquid oxygen –

- **Pressure swing adsorption (PSA)** In a PSA plant the method used is – there are two vessels filled with Zeolite Molecular sieve adsorbers. (Fig.1). The compressed air passes through one of the adsorbers wherein the molecular sieve adsorbs nitrogen from the air. The process makes oxygen escape the adsorber and is collected as a gas. After the nitrogen overflows the adsorber, the inlet flow is changed to the second adsorber. The first adsorber starts eliminating nitrogen by keeping the pressure down. This pressure is repeated between high pressure and low-pressure multiple times. The pressure swing adsorption (PSA) process is a reliable economical autonomous oxygen production process ideally suited to hospitals in developing countries.[5]

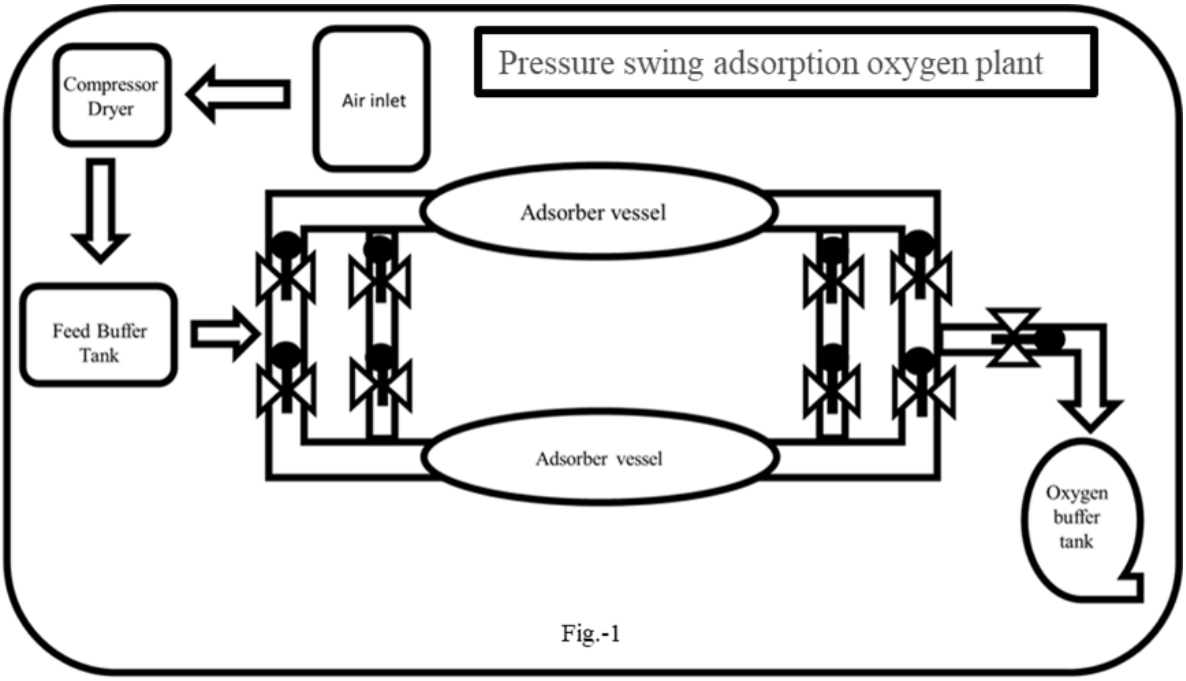

Fig. 1 - Pressure swing adsorption plant

Oxygen concentrators – It works on the PSA method and can be used as a portable machine for home use. They are convenient, safer and portable alternative to pressurised oxygen cylinders. Hence despite of few limitations

(Like initial cost, battery life and need for electricity) it can be used at home and isolation centres for covid 19 patients of mild to moderate disease.

Oxygen cylinder vs portable oxygen concentrator –

	Oxygen cylinder	**Portable oxygen concentrators**
1.	Finite use.	As long as battery powers machine.
2.	Delivers oxygen with continuous flow.	Varies with type of machine,
3.	Leakage increases risk of fire.	Safer.
4.	Bulky.	Portable.

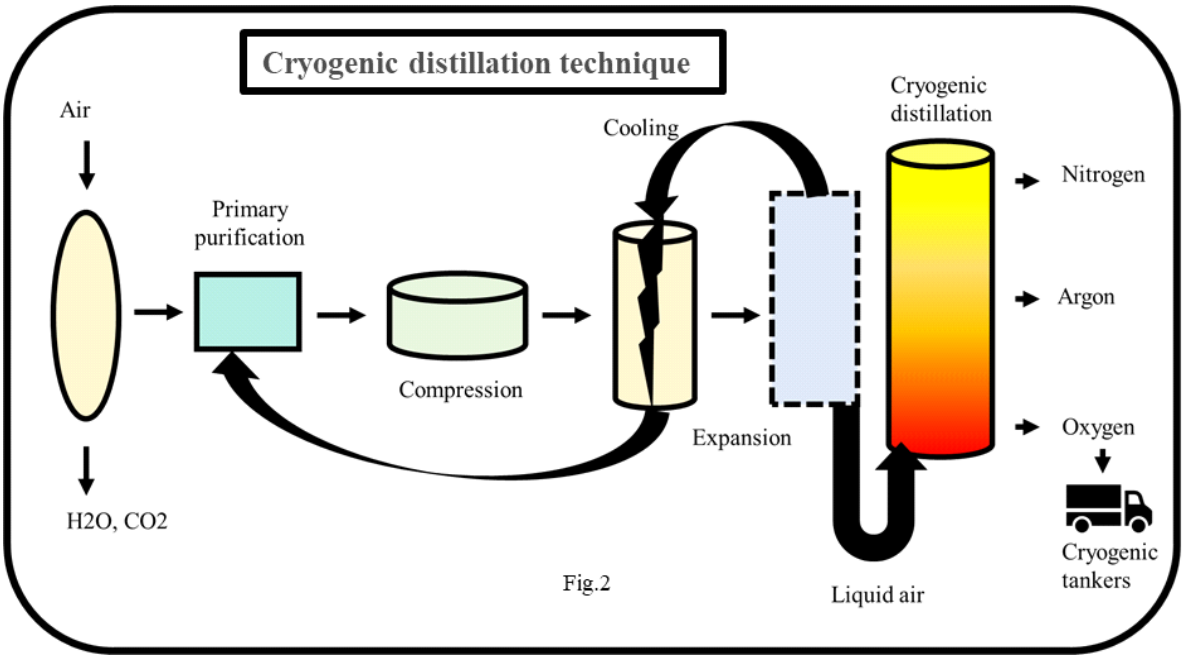

Fig. 2 - Cryogenic distillation technique.

2. Cryogenic distillation technique

Atmospheric oxygen is cooled until it gets liquefied and distilled at its boiling point of -183 degree Celsius. This technique can be used for generating industrial gases such as oxygen, nitrogen and argon. The process was pioneered by Carl Von Linde in 1930s and is still being widely used worldwide. It is ideal for generating very high purity oxygen.[6] Energy for cooling oxygen to cryogenic temperature is obtained by the compression of the air. In order to get low distillation temperatures cryogenic oxygen plant needs a refrigeration cycle and cold equipment that must be placed within an insulated closure and is commonly known as cold box. The energy to run refrigeration cycle uses expansion turbines. When the air is compressed, it is passed through a cleaning system where vapor, carbon dioxide and hydrocarbons are eliminated. Then the compressed air is passed into high pressure distillation column where vaporous oxygen is formed at the top of the column and nitrogen is formed at the bottom of the column. (Fig. 2)

Transportation and storage –

The cryogenic tanks consist of - Outer & Inner Tank. Stainless steel is used to make the inner tank and Carbon steel is used for outer tank. Perlite aggregation is used to fill the gap between tanks and super insulation by vacuum technology. The tanks are manufactured as follows: Tanks are produced to store the inner gas, at a temperature -196 ºC or at a less temperature, based on different design parameters. LIN, LOX, and LAR cryogenic storage tank capacities range from 300 gallons to 80,000 gallons (equivalent to 50 tons). Vaporizers with capacities which ranges from 700 SCFH) to 35,000 SCFH per unit are also available.

Oxygen physiology –

Oxygen supply through the respiratory system and its diffusion into tissues by the circulatory system are necessary for survival. The partial pressure of oxygen (PaO_2), marks the balance between oxygen delivery and its consumption. In mammals, oxygen is transported by red blood cells circulating in a well-organized vasculature of arterial and venous systems. Partial pressure of dissolved O_2 in arterial blood which lies within the normal range of 80-100 mmhg.[7]

The single breath count tool

Method –

1. Take a deep breath
2. Counts from 1 to 30 in a single breath.
3. Record the time taken to count 1 to highest number, in seconds.
4. Ask the patient to take three further deep breaths

5. Repeat from steps 1 to 3

Another way is the Breathlessness Screening Tool (BST) where the patient counts from 1 to 30 in their own language. Maximum number of counted numbers in a single breath is < 7. Time between consecutive breaths < 5 sec corresponds to $Sp0_2$ < 90% (on room air) with sensitivity of 87% and specificity of 82%. Maximum number of counted numbers on single breath < 10 OR time between consecutive breaths < 7 sec corresponds to $Sp0_2$ < 95% (on room air) with sensitivity of 91% and specificity of 93% [8,9,10]

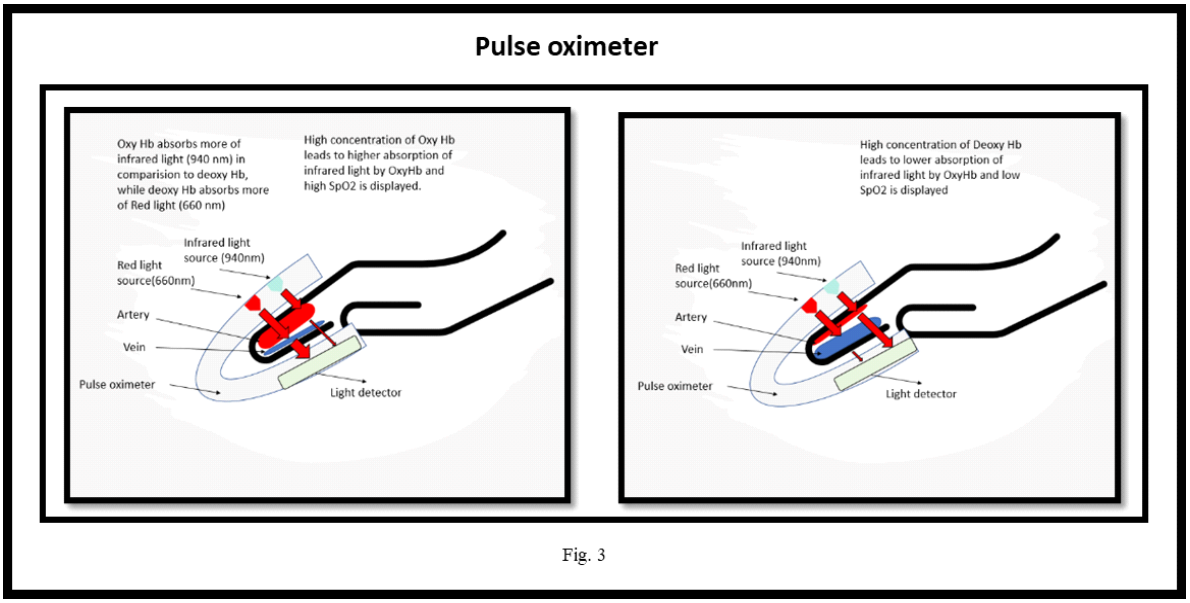

Fig.3 - Pulse oximetery.

Pulse Oximetry – Pulse oximeter use increases resource utilisation.[7] Oxygen combines with haemoglobin to form oxyhaemoglobin. It uses absorption of specific waveforms of light to compare wavelengths of oxyhaemoglobin and deoxyhaemoglobin. SaO2 is the ratio of Oxygenated to total haemoglobin, it is a lesser invasive indirect marker of PaO2. (Fig.3). Arterial blood is about 98% saturated, so bright red, and the venous blood is about 75% saturated and is dark red. Pulse oximeter probe have light emitting diode which shines through the tissue and picked up by a sensor on the other side, oximeter can determine the haemoglobin in pulsatile blood (arterial), and then determine SpO2. As per American Thoracic Society supplemental oxygen is given if the reading is below 89. Pulse oximeters are reliable indicators of SpO2 and pulse rates in physiological and also in patients with various comorbidities. However, the correlation decreases with conventional pulse oximeters during hypoxaemia. Measurements are not affected adversely by Skin tone.[11]

Arterial blood gas saturation –

It gives more accurate measure of O2 and CO2 in blood, but it is an invasive technique. It is proven that implementation of precise control of arterial oxygenation may avoid the harms associated with excessive and inadequate oxygenation.[13] Partial pressure of oxygen (75-100 mmHg) and CO2 in blood, and blood pH (7.38 – 7.4). Oxygen therapy is given to patients if PaO2 is < 60 mmHg.

Ventilation – The process of normal spontaneous breathing which includes inhalation and exhalation. If the patient is unable to do this on their own, ventilator does this for them. Ventilation includes both delivery of oxygen and removal of carbon dioxide from the lungs.

Oxygenation – It is only the first part which is delivery of oxygen to the tissues.

Oxygen therapy Vs Ventilation –

Hypoxemic respiratory failure – When lungs are not able to absorb oxygen adequately. It generally occurs due to acute lung disease causing fluid or sputum to occupy alveoli. Such patients should be treated with Oxygen therapy.

Hypercapnic respiratory failure – There is ventilation issue leading to low oxygen and high carbon dioxide levels. This condition generally requires ventilator support. (Fig.4)

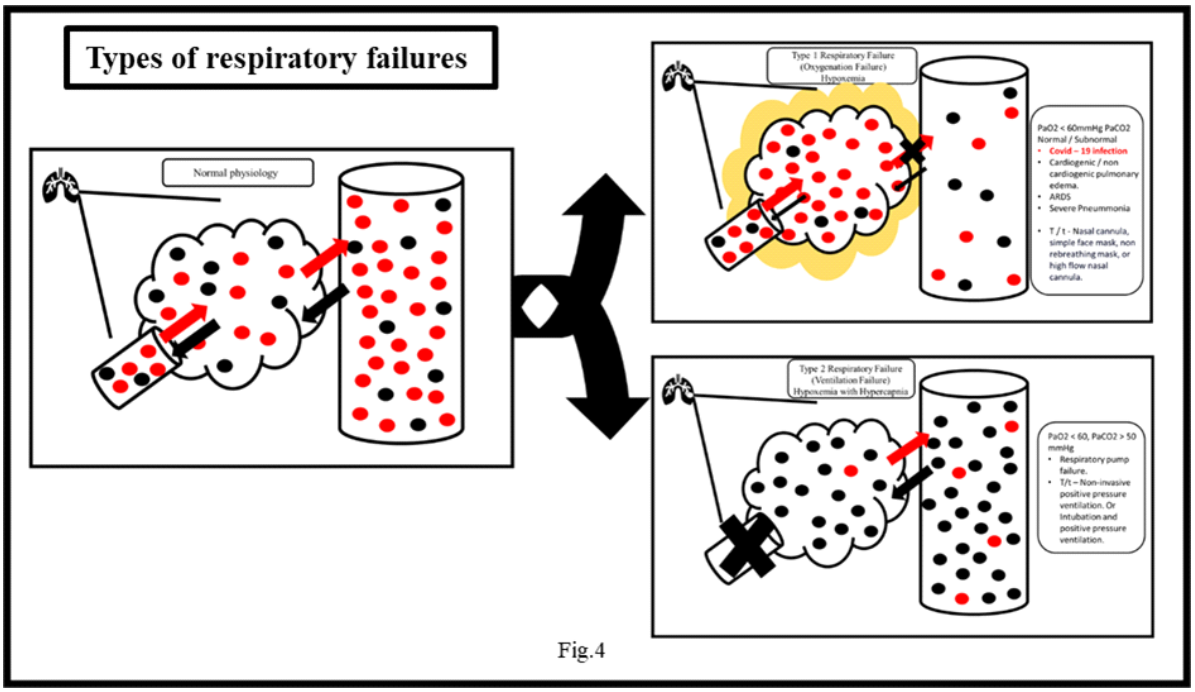

Fig 4: Types of Respiratory failures

The final concentration of oxygen delivered does depend on the ventilatory needs of the patient, the oxygen reservoir size, and the rate at which the reservoir is filled. At a constant flow, the tidal volume is inversely proportional to the FiO_2. While, the high-flow systems provide a constant FiO_2 by delivering the gas at flow rates that exceed the patient's peak inspiratory flow rate and by using devices that entrain a fixed proportion of room air.[14]

Type 1 respiratory failure is produced in maximum patients with Covid 19 infections, except in very severe infections with altered sensorium. And explosion of number of cases presses the need for home isolation and oxygen therapy there. A Comprehensive COVID-HOT (home oxygen therapy) protocol is given by the Joint ACAIM-WACEM COVID-19 Clinical Management Taskforce (CCMT) . (Fig. 5,6)

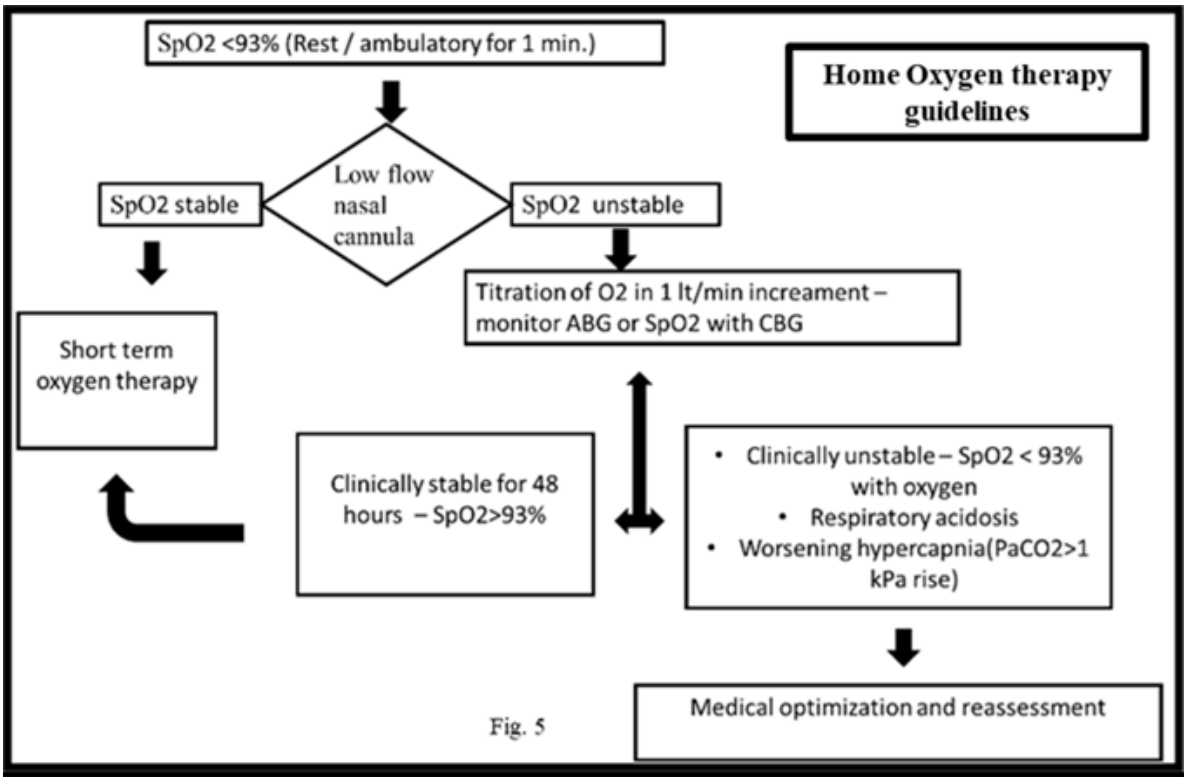

Fig. 5

Clinical parameter	High risk catagory
SpO2	<93%
Heart rate	<45 / >120 / min
Temperature	<35 / >38.5 ° C
Respiratory rate	<12 / >20 breaths / min

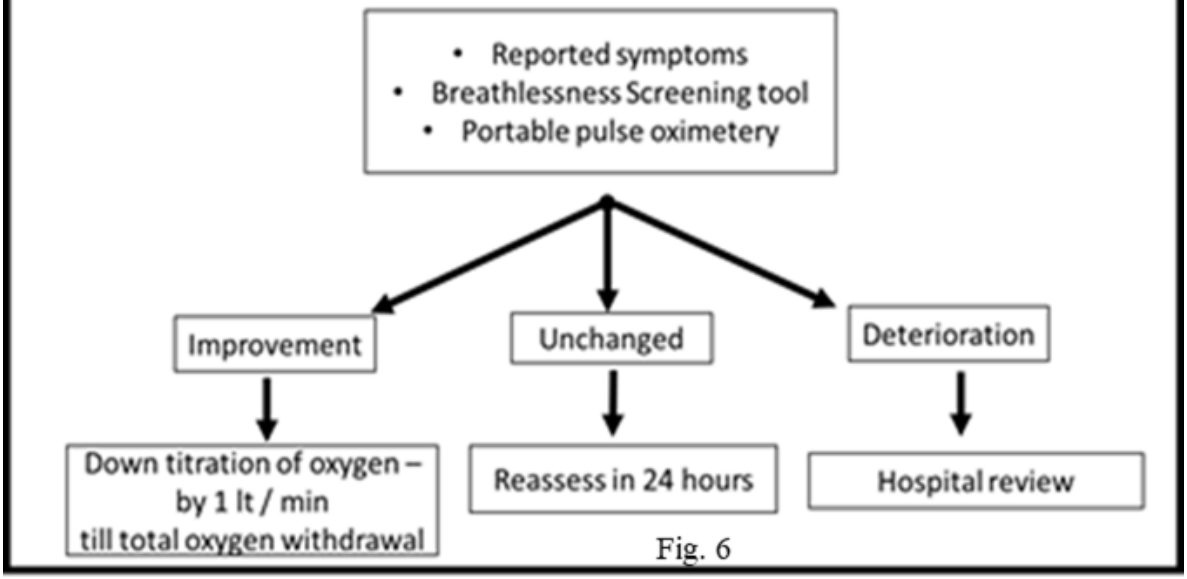

Fig. 6

Fig 5, 6: Home Oxygen therapy guidelines

Short term home oxygen therapy and monitoring for Covid-19 infection –

The ACAIM-WACEM Clinical management taskforce emphasizes strongly that the COVID-Home oxygen therapy protocol should only be used with utmost caution, fully leveraging the collective clinical team experience and hardwired secondary confirmatory assessment by a senior provider before proceeding, and never in the setting of a single health care provider acting in isolation.[15] The use of Short-term oxygen therapy in COVID-19 patients is based on the primarily hypoxic pathophysiology of SARS-CoV-2 pulmonary damage.(Fig. 5,6)[16,17]

Oxygen therapy and monitoring in hospitalised Covid 19 patients – Among the various modalities and their respective indications of oxygen therapies in hospitalised Covid 19 patients (Fig. 7) the most frequently used is High flow nasal cannula. Few of the pertinent features while treating a Covid 19 patient are –

- Proper sized nasal cannula.
- Suitable placement.
- Unobstructed airway.
- Goal must be to maintain an oxygen saturation above 95%.
- Use of surgical mask to prevent aerosol generation.[18]

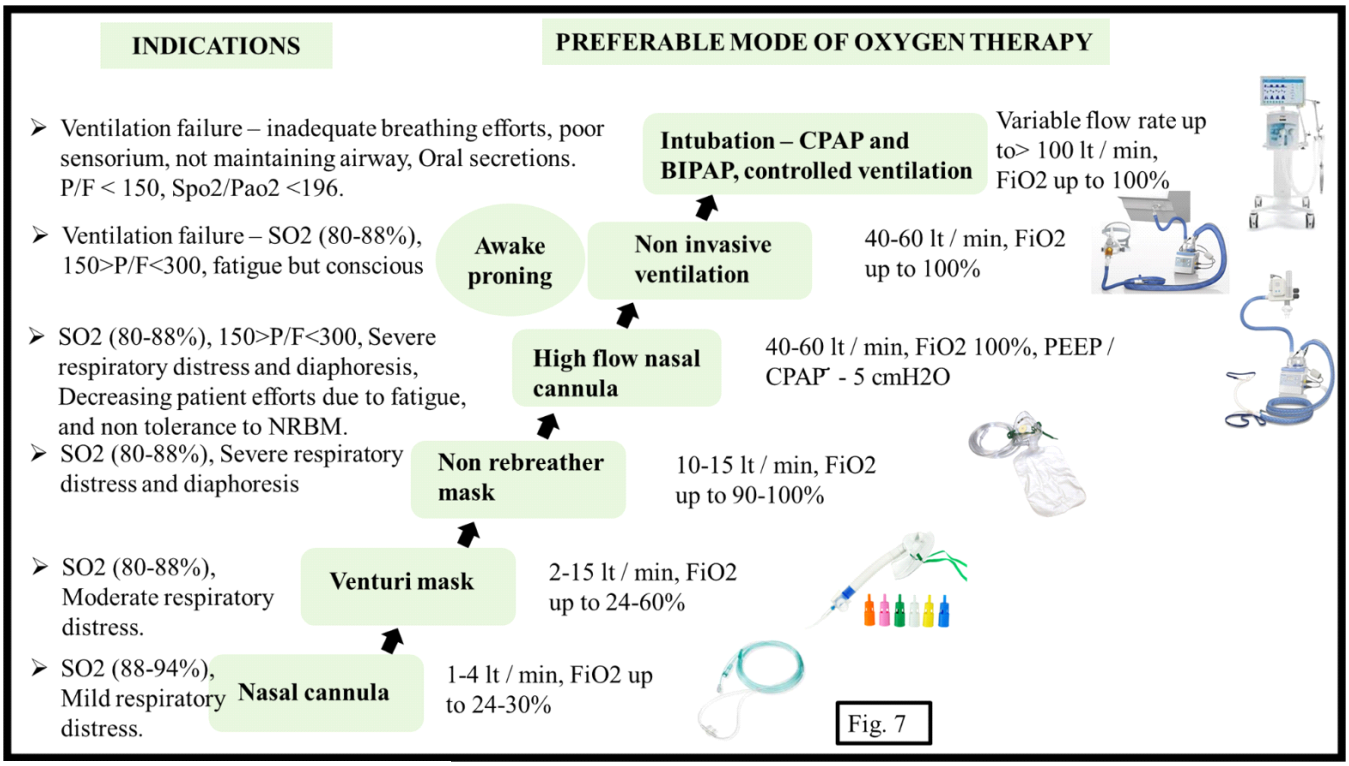

Fig 7: Preferable mode of oxygen therapy

The mortality of invasively ventilated patients is high and it is not easy to extubate many of these patients. This raised the concern that it is being underutilized to avoid intubation and to facilitate extubation.[19]

Awakeproning – This manoeuvre has following advantages -

- Reduces alveolar overdistension in the nondependent areas.
- It allows opening of collapsed alveoli in the dependent areas – improving ventilation perfusion mismatch and shunt.
- Decreases compression and hence increases perfusion of dorsal lung alveolus.
- May facilitates drainage of respiratory secretion from dorsal lung.[19]

Oxygen therapy in Low flow vs high flow oxygen therapy –Low flow oxygen therapy – Flow rate of 5-10 lt / min. Patient has to inhale from room air to compensate for balanced inspiratory flow requirement. Rebreathing does occur as mask is not totally flushed for expired carbon dioxide. For lower flow rate of 1-4 lt / min humidifier is not required. It is not suitable for acute hypoxia.

High flow oxygen therapy – This can match or exceeds normal inspiratory flow rate, at 20-30 lt / min. Systems can generate 2-120 lt / min of flow rate.

High flow nasal cannula Vs Ventilator –

Components of a high flow nasal cannula –

- Flow generator.
- Air-oxygen blender.
- Humidifier.
- Heated tube.
- Delivery device – nasal cannula

Components of a Ventilator –

All components of HFNC with breathing control, monitoring systems and alarm system for safe, controlled and programmable ventilation.

Important parameters for programming mechanical ventilation are:

- The ventilation mode (volume, pressure or dual),
- Modality (controlled, assisted, support ventilation), and
- Respiratory parameters. The parameters that are important are peak pressure (in pressure modalities), respiratory frequency, positive end expiratory pressure, inspiratory time, inspiratory flow, inspiratory-to-expiratory ratio, support pressure, time of pause, trigger sensitivity, and expiratory trigger sensitivity, and in volume modalities it is tidal volume and minute volume etc.

Alarms – To detect problems in the ventilator and changes in the patient, alarms for tidal and minute volume, peak pressure, respiratory frequency, FiO2, and apnoea are available.

Ventilation could be Invasive or Non-invasive. A tube is inserted through mouth to the lungs to assist in ventilation in case of invasive ventilation.

Intubation is mostly avoided by physicians due to the difficulty in managing the patient because of its deleterious effect. Other advantage is better CO2 clearance as the upper airway dead space is continuously being flushed. This reduces work of breathing and alsoensures high FiO2. HFNC is better as it provides a very good patient comfort through warm and humid gas flow delivered by nasal prongs at a relatively steady rate. for the patient and improves oxygenation. Intubation may cause injury to lungs, trachea or throat. Ventilation has a higher risk of – Fluid accumulation, aspiration and Lung complications.

NIV may however results in high tidal volumes by pressure support and that may potentially worsen the pre-existing lung injuries.

High flow Vs Low flow Oxygen therapy-Variable pressures are generated in airways as per the patient's breathing effort due to the constant flow rate of gas in the HFNC system generates.In comparison, the use of intubation may be reduced by the use of high flow oxygen therapy.

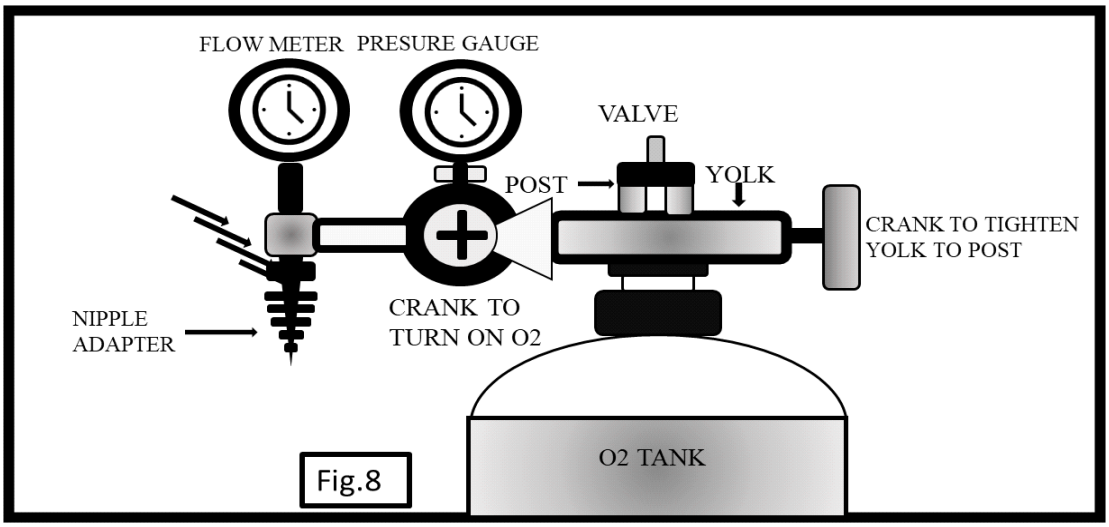

Fig 8: Oxygen cylinder

Oxygen cylinder – An O2 tank is a storage vessel, which is either holds oxygen under pressure in gas cylinders or as liquid in a cryogenic storage tank. Oxygen tanks are used to store gas at medical facilities. Oxygen at home is mostly not held at pressures higher than 200 bar / 3000 psi because it triggersfire by high temperatures caused by adiabatic heating when themovement of gas from one vessel to the other produces change in pressure.

To reduce the risk of fire any equipment that is coming into contact with high pressure oxygen must be "oxygen clean" and "oxygen compatible". Removal of any substance that could act as a source of ignition is known as "Oxygen clean". "Oxygen compatible" means that internal components are not inflammable or easily degradable in a high-pressure oxygen environment.

Conclusion – The unprecedented need of oxygen in ongoingCovid 19 pandemic related hypoxemic respiratory failure pushed the need for increased production, storage and transportation of oxygen. It also made it necessary to train healthcare personnel regarding when and how to administer oxygen to a Covid patient at home and in the hospital. The protocols may need a revision as and when the knowledge of pathophysiology improves.

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