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Some Important Points in Oxygen Therapy: An Update for the Clinicians in the Covid Era

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Abstract

The use of oxygen has gained much prominence in the Covid era. However, there are still lacunae in the practical knowledge of health workers regarding proper use of this medical gas. Daily clinical experience still reveals instances of over- and under-use of oxygen. There are various aspects of oxygen use, including choosing the proper source, the proper delivery device, and the proper duration, which must be decided appropriately for maximum benefit of the patient. This article aims to present certain practical aspects of oxygen use for the clinician. While this is an essential knowledge for the Covid era, the learning will be useful for the future too.

Key words: Venturi mask; hyperbaric oxygen therapy; minute volume; HFNC; wound healing.

Introduction

In the Covid era, the use of oxygen has become very common in all patient care settings, whether indoors or outdoors. This has given rise to a lot of confusion and controversy in the initial days. Practically, very few clinicians or nurses have a complete knowledge of the proper use of oxygen and this lack of knowledge leads to the risk of both over- and under-utilisation[1]. Hence, a comprehensive review of the various aspects of oxygen use is an essential tool for every physician.

First of all, it must be reiterated that oxygen is a drug. It is a life-saving drug not only for Covid, but also various other indications. Therefore, like all other drugs, its use must be guided by evidence and protocols. With the mass-scale availability of cheap finger pulse oximeters in the market, the oxygen saturation of any patient may be assessed anywhere, even at home. While this is a great way to monitor oxygen therapy anywhere, on the flip side it also raises the possibility of unnecessary treatment. As the last section of this article will show, oxygen excess is also as harmful as oxygen deficiency. Thus, a goal directed oxygen therapy is the ideal way to benefit the patients with minimum harm.

In this article, the authors have endeavoured to discuss some aspects of oxygen use, which are needed in day-to-day clinical practice.

The oxygen source

For healthcare facilities, we need medical grade oxygen. This is defined as at least 90% V/V of oxygen in the supplied gas. Carbon monoxide must be less than 5 ppm. In hospitals, oxygen is delivered either from a wall socket or a cylinder. The wall socket is usually connected to the oxygen plant or reservoir tank of the hospital by a pipeline. For connecting to a ventilator, the wall socket type source is ideal as it ensures uninterrupted flow.

For reservoir tank of a hospital, the best option is LMO (Liquid medical oxygen). As the name implies, the reservoir tanks hold liquefied oxygen at -183° C. This is a great source of large volume oxygen supply as 1 litre of LMO is equal to 870 L of gaseous oxygen. Also, LMO can provide the purest form of oxygen (> 98%). For installation of LMO tank, medical gas pipeline system throughout the hospital is a must. Usual capacity of LMO tank varies from 2 to 20 Kilo litres. LMO is always generated off-site and delivered to the hospital.

Another type of oxygen plant in hospitals is the PSA plant (Pressure Swing Adsorption). In this plant, the ambient air passes through a filtration system where the nitrogen is separated. The resultant oxygen has varying purity. However, PSA plants are ideal for remote hospitals where daily supply of LMO is impossible.

Even if a hospital has oxygen tank, it is mandatory to keep 2 - 3 days' supply of oxygen in cylinder form. The cylinders come in various sizes (Table I). Oxygen cylinders should have a black body with white shoulder. The various sized cylinders are given alphabetical codes like B, D, E, etc[2]. These cylinders hold pressurised oxygen and the exact volume of oxygen in a cylinder depends on the filling pressure[2]. Each cylinder should have a label indicating the volume of oxygen and the pressure. Cylinders are good for

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bedside oxygen therapy and patient transport.

Table I: The various types of Oxygen cylinders for medical use.

Type	Gas Capacity (maximum gas volume when full: litres)	Pressure (psi)
B	200	1,900
D (commonest for home delivery)	400	1,900
E (commonest in anaesthesia)	660	1,900
F (commonest in hospital wards)	1,360	1,900
H	6,900	2,200

Recently, oxygen concentrators have become very popular, especially for home use[3]. As the discussions below will show, these are not good for hospital use. A concentrator (or generator) extracts the oxygen from atmospheric air. These are basically portable forms of PSA plants described earlier. Maximum oxygen flow rate obtainable from this device is 5 LPM (litres per minute). The expected purity of oxygen is 87 - 96%. If the purity falls below 85%, it is not acceptable. Thus, for patients with high oxygen demand, this is not useful.

There are high flow concentrators that can generate flow rates of up to 10 LPM[3]. But these are extremely costly. For example, a 5 LPM concentrator now costs around 30,000 - 50, 000 INR. An 8 LPM concentrator costs around 60,000 - 70,000 INR. But for 10 LPM machines, the cost crosses 100,000 INR. The device has two other disadvantages: it must be switched off after 3 - 4 hours of continuous use. Thus, it cannot ensure uninterrupted oxygen delivery. Also, it is run on electricity. Thus, it is not suitable for use during transport unless the car has electrical socket. Also, at higher flow rates, the purity of delivered oxygen falls considerably.

Does oxygen need humidification?

It is a standard practise to humidify oxygen (by bubbling it through water). This prevents drying of nasal mucosa and discomfort. But it has been seen that for low flow oxygen (~ 4 LPM), dry or humidified oxygen does not make much difference. Oxygen coming out of a concentrator is partly humidified.

But for high flow cases, esp. HFNC, humidification is a must. The water used for the process must be medically distilled water or normal saline. Tap water should not be used as it contains microorganisms like fungus which can be aerosolised and inhaled by the patient. The water must be changed daily.

Types of oxygen delivery devices

There are various types of oxygen delivery devices in use. Also, it must be remembered that oxygen delivery is required in various settings: during an emergency, in hospital, during transport and currently (post-Covid) at home. Thus, while efficiency of gas delivery is definitely of prime importance, other factors like ease of use and safety must also be considered while choosing a delivery device. The paragraphs below give a brief account of the common delivery methods. There are two types of delivery devices: High flow and low-flow[3]. Low flow systems deliver oxygen up to 15 LPM. In low-flow settings, the oxygen gets diluted by inspired air. Thus, the FiO_2 cannot be calculated accurately. But in high flow devices, the FiO_2 can be fixed quite accurately.

Nasal cannula

Nasal cannula is the ubiquitous low-flow oxygen delivery device. It is a plastic cannula with two terminal prongs for oxygen delivery directly to the nostrils. The advantage of this device is that the patient is able to eat or talk while on oxygen. The cannula is easy to use and even non-medical care givers can be taught to attach it to the patient. Studies have also shown that patients prefer this mode of delivery. But the prongs can get dislodged from the nostrils during any movement and in patients with nasal obstruction, obviously this is futile. Also, another disadvantage is that the FiO_2 varies with the breathing pattern of the patient and the minute volume. The following table (Table II) shows the approximate FiO_2 according to the flow rate of oxygen.

Table II: Table showing FiO_2 in nasal cannula according to oxygen flow rate.

Oxygen flow rate (LPM)	FiO_2 (%)
1	24
2	28
3	32
4	36
5	40
6	44

For flows greater than 6 LPM, often the patient experiences considerable discomfort and nasal drying and it is better to switch to other delivery devices. Also, for higher rates of oxygen flow through the cannula, the FiO_2 becomes more variable.

But nasal cannula is the cheapest delivery device and especially suited for home oxygen, (e.g., post-Covid). Since home oxygen source is mostly the oxygen concentrator (highest flow rate 5 LPM), the nasal cannula is aptly suited for the role.

Face mask

Face mask is the next level of delivery device. There are many varieties. One common problem with all varieties is claustrophobia[4]. For some patients this may be a limiting factor.

Simple oxygen mask

This one is a plastic mask with exhalation holes on the sides. This prevents CO_2 rebreathing. The mask is held in place by elastic straps going round the back of the head. It must be remembered that an oxygen mask operates properly only at flow rates of 6 - 10 LPM. Very low flow oxygen (1 - 2 LPM) is not suitable through a mask. At the proper oxygen flow rate, the FiO_2 achieved is 35 - 60%. Thus, oxygen concentrators can not be used with a face mask (as their flow rates is below 6).

An oxygen mask is suitable for short (typically < 12 hours) periods of oxygen delivery. However, disadvantage of the device is that unless the mask is sealed properly around the nose and mouth, the oxygen gets diluted. Also, a patient cannot eat or drink while on mask. During meal times, the patient must be shifted to nasal cannula.

Partial rebreather mask

The above two devices are low-flow systems. But a re-breather mask is a high flow oxygen delivery device. A re-breather mask has a reservoir bag attached to the oxygen pipe just before it joins the mask port. There are separate exhalation ports on the sides of the mask. The bag and the ports have one-way valves. Thus, the exhaled air goes out only through the exhalation ports. After that, when the patient inhales, he/she takes the pure oxygen from the bag through the valve (for a partial re-breather mask, some air is mixed with the oxygen). For this reservoir bag to work efficiently, the oxygen flow must be maintained at a minimum of 6 LPM and the bag should be partially inflated during inspiration. For optimum functioning, the oxygen flow rate should be 10 - 15 LPM.

This mask provides FiO_2 of up to 80%. This mask is ideal for patient transport or quickly oxygenating the patient before intubation, etc.

Non-rebreathing mask

This mask is similar to the previous one. But the valves of the reservoir bag are more efficient to ensure that none of the exhaled air enters the oxygen reservoir. Hence, the FiO_2 is higher and may reach 100% at flow rates of 15 LPM. However, the precise FiO_2 is difficult to calculate.

Venturi mask

Venture mask is a high flow oxygen delivery device. The main difference of this device with the others mentioned here is that it allows a precise FiO_2 to be delivered[5]. This mask comes with color coded jet adaptors. Each adaptor corresponds to a particular FiO_2 at a particular oxygen flow rate. Thus, for venturi masks to be used, a precise oxygen flow rate has to be ensured. The following table 3 describes the colour coding of these masks

Table III: Table showing oxygen parameters of venturi mask.

Colour	Oxygen flow rate (LPM): minimum	FiO_2
Blue	2	24
White	4	28
Orange	6	31
Yellow	8	35
Red	10	40
Green	15	60

The oxygen flow rate given in this table is the minimum rate required for achieving that FiO_2. If the oxygen flow rate is higher, the same FiO_2 is achieved but total air delivered to the patient is higher. For example, in the red adaptor, min flow rate required is 10. If the flow rate is 12 or 14 LPM, the FiO_2 is still 40. But total minute volume delivered to the patient is higher for higher flow rates. If the COPD patient is dyspnoeic with high minute ventilation, then it is advisable to use the higher rates of oxygen flow for that coloured adaptor so that the total delivered air matches the minute ventilation[5].

Venturi mask is especially suitable for patients with COPD where excess oxygen use can precipitate a carbon dioxide narcosis[5]. Thus, in such cases, precise oxygen delivery is needed. But since oxygen flow rate needs constant monitoring, this mask is not suitable to be used at home. Also, for the FiO_2 to be achieved, a good seal around the mask is needed.

Oxygen hood

An oxygen hood is a plastic dome or box that is used for infants. This is placed over the baby's head so that he/she can breathe in the oxygenated air without getting stimulated by a skin-touching facial contraption like a mask. A similar device is an oxygen tent.

Face tent

This is a wide plastic mask that covers the mouth and nose but does not form a seal around them. This is thus, essentially a low flow system.

This is ideal for patients with facial trauma or burns or for those who are too claustrophobic. The oxygen flow rate must be kept high (around 15 LPM) as there is no seal and the oxygen gets diluted. The FiO_2 naturally is variable.

Transtracheal oxygen catheter

As the name implies, this device is inserted percutaneously into the trachea[6]. Oxygen is delivered directly to the trachea, bypassing the dead space. But this method is not very popular due to the invasive nature of the procedure[6].

HFNC

High flow nasal cannula (HFNC) device has become very popular in the Covid era. As the name implies, this is a cannula where gas flow rate is increased massively[7]. But that is not the only function of this device. It also humidifies the oxygen and in this machine, the FiO_2 can also be fixed. While in conventional nasal cannula the maximum FiO_2 achieved is around 40%, in HFNC the maximum can be 100%[7]. The flow rate can be increased up to 60 LPM, although in some modern devices it can be even higher at 90 LPM. These two parameters can be adjusted independently.

In the usual oxygen delivery devices discussed till now, humidified oxygen comes from the cylinder and the cannula or the mask just acts as a conduit. But in HFNC, the machine itself has the means to humidify the gas. This is essential, as flow of dry gas at 50 or 60 LPM through the respiratory tract would cause immediate mucosal injury.

When a dyspnoeic patient is having high minute ventilation, the oxygen delivered through the nasal cannula is not enough as the patient is also breathing through the mouth. Thus, the oxygen gets massively diluted. But an HFNC, by increasing nasal flow, reduces the mouth breathing, and thus reduces dilution of the oxygen delivered.

Also, the HFNC reduces the dead space in the pharynx and increases efficiency of breathing. HFNC can never be used at home and is only suitable for hospitals which have assured constant high flow oxygen.

For type 1 respiratory failure, NIV was the preferred therapy earlier. But now, the American College of Physicians have recommended the use of HFNC as first-line in suitable cases[8].

Some other modes of oxygen therapy

The preceding section discussed the various devices that are used to deliver oxygen to the patient. The next section will briefly discuss two other methods of oxygen treatment which are used for limited indications.

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBOT) is a completely different treatment method. This is only used to treat conditions like gas gangrene, decompression sickness, carbon monoxide poisoning, or cyanide poisoning[9].

In this therapy, the patient is put inside a hyperbaric chamber where 100% oxygen is delivered at 1.5 - 3 times the atmospheric pressure. Each session lasts 2 - 3 hours. This delivers more oxygen to the tissues compared to oro-nasal delivery and also can inhibit the growth of certain bacteria[9]. This also promotes vasculogenesis. Multiple sessions may be needed, and in the USA, this is covered by insurance. Since the therapy takes place inside a high pressure chamber, it is not suitable for persons with middle ear surgery or tympanic perforation.

Topical oxygen therapy

In hyperbaric oxygen therapy, the patient is put inside a chamber and oxygen at supra-atmospheric pressure is delivered to the chamber. But this involves subjecting the entire body to high pressure oxygen, which may have untoward consequences. Thus, local delivery of oxygen only to the body part needed is an attractive idea.

As the name implies, Topical Oxygen Therapy (TOT) involves delivering oxygen directly to the body area of interest[10]. This is an experimental therapy which is becoming popular now. In diabetic non-healing foot ulcers, local oxygen therapy can sometimes help in wound healing[10]. The oxygen source is connected to a large plastic cover which is wrapped around the infected foot in an air-tight manner (like a plastic boot). The oxygen may be delivered either at normal or supranormal pressures.

There are three main types of devices for local oxygen delivery:

I. Continuous low flow oxygen diffusion device

II. Constant pressure delivery device

III. Cyclical high pressure delivery

However, the use of TOT is still controversial. A lot of physicians are still sceptical of its utility. Earlier data regarding the efficacy had been controversial, but recently some small trials have shown marked favourable results. This therapy must be used for a prolonged time for perceptible benefit[11].

Side-effects of oxygen therapy

As discussed previously, excess oxygen is quite harmful. In the critical care setting, it is often found that patients are given oxygen till the SpO_2 reaches 100%. Not only is this unnecessary, *but some recent studies have found this to be positively harmful*[12]. Thus, patients should not be maintained on SpO_2 of 100% for prolonged periods. For normal patients, the target saturation is anything above 94%[12]. But 98% is the upper limit. For COPD cases, the target saturation is 88 - 92%. Excess oxygen therapy leads to some problems:

Absorption atelectasis

Continuous high flow oxygen therapy leads to replacement of alveolar nitrogen with oxygen. Nitrogen is not absorbed from the alveoli. Thus, it maintains the patency of the alveoli. If oxygen replaces that nitrogen, then the oxygen will be quickly absorbed in the blood. Thus, gas volume inside the alveoli falls and this can cause collapse of the lung units[13].

Retrolental fibroplasia

This is a disease of premature infants (< 31 weeks) who are given excess oxygen. There is fibrovascular proliferation in the retina[14].

Conclusion

In conclusion, oxygen is a life-saving drug. But it must be used judiciously. Like all other drugs, oxygen must be used only for the minimum duration needed and in proper concentration. Proper delivery devices must be chosen considering the target SpO_2, comfort of the patient, and condition of the lungs. The need for oxygen in a patient must be reviewed daily during the clinical rounds.

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