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Review article

Practical Aspects of Oxygen Therapy

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INTRODUCTION

Oxygen is one of the most important "drug" prescribed in the intensive care unit both for adult and for paediatric patients. Much of the facts about oxygen, its metabolism, storage and delivery systems is already known. This article gives a comprehensive and most important facts about oxygen therapy.

In 1772 Carl Wilheim Scheele named it as "Fire air" after observing the fact that it is necessary for the combustion of materials. Later in 1774, Joseph Pristley discovered it as a normal constituent of air and put forth its importance. Further in 1777, Antonie-Laurent Lavoisier demonstrated that this air is absorbed by lungs and after metabolism eliminated as carbon di oxide. Hence he named it as "Vital air" and "Oxygen"[1].

The term oxygen cascade is given to the gradients of partial pressures of oxygen while it travels from atmospheric pressure in to the mitochondria through the respiratory passage. If we take the atmospheric pressure of 760 mm Hg and the atmospheric oxygen content as 21% then the atmospheric partial pressure of oxygen becomes 160 mmHg (normal- 140 to 160 mmHg). In the trachea it is about 130-150 mmHg, alveolus about 105 to 110 mmHg. In normally oxygenated artery it is 100 mmHg, tissue it is 40 and in mitochondria it is 2 mmHg.

It is important to note that the PaO_2 value depends upon the atmospheric pressure, temperature, inspired air oxygen content and the age of the patient. More the atmospheric pressure and FiO_2, more the PaO_2. PaO_2 will be relatively low at extremes of age for a given atmospheric pressure and FiO_2.

Oxygen is carried to the tissues by blood in 2 forms[1,2]

1) Simple solution- as a mixture in plasma, about 2 ml/ 100 ml of blood.

2) In combination with hemoglobin- the most important route of oxygen delivery. Nearly 1.34 ml of oxygen is carried by 1gm of adult hemoglobin. Hence if Hb level is 15 gm% then 100 ml of blood carries nearly 20 ml of oxygen. Hence oxygen flux will be 1000 ml/ min.

i.e. oxygen flux = CO x Hb x 1.34 x SpO_2 = 5 ltr x 15 x 1.34 x 98 = 1000 ml/min.

The oxygen dissociation curve shows the saturation of hemoglobin to a particular value of partial pressure of oxygen. It is of a clinical significance where in we can roughly estimate the PaO_2 value depending upon the SpO_2 value.

Oxygen Hemoglobin Dissocian Curve

This curve indicates that a small change in PaO_2 will alter the SpO_2 to a greater extent during its steeper part. That is a higher PaO_2 (or FiO_2) is necessary to increase a small

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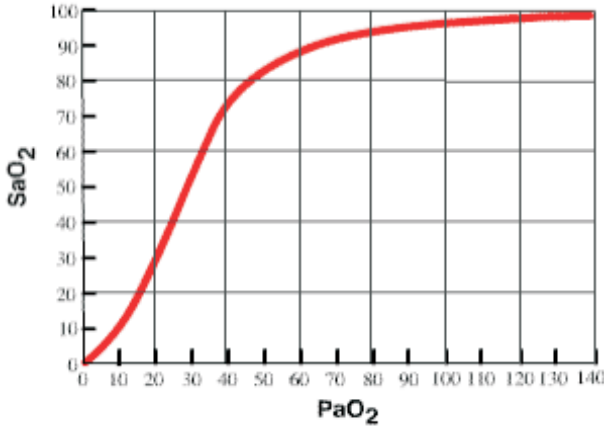
Fig. 1: oxygen hemoglobin dissocian curve



percentage of saturation of Hb. The conditions which cause this curve to shift to right (Bohr effect) are academia, hyperthermia, increased CO_2 levels and increase in 2-3 BPG levels. Hence in acidosis, hyperthermia or hypercarbia a higher inspired oxygen is needed to produce same SpO_2 levels.

Goals of oxygen therapy

are to 1) relieve hypoxemia, 2) to prevent development of hypoxemia, 3) reduce work of breathing, 4) to decrease the load on myocardium and 5) to improve exercise tolerance.

The indications for oxygen therapy is hypoxia either manifest (SpO_2 < 92%) or compensated (increased respiratory rate, work of breathing, decreased activity).

Oxygen sources[1,3] .

Sources are the equipments from which oxygen is used. They are

1) Oxygen cylinders
2) Liquid oxygen containers and
3) Oxygen concentrators.

Oxygen cylinders

The cylinders are filled with oxygen under high pressures. These are the most common sources in day to day practice in any institution or private hospitals. They are widely available, they deliver reliable purity of oxygen, simple to maintain. Their disadvantage is their high cost, bulky and unsightly equipment and they are not portable in all the situations.

It is very important to know how long does a cylinder last rather than of what size is the

Table 1: Cylinder sizes and their capacity[3]

SIZE	VOLUME (M^3)	USE
G	7.6-8.8	Hospital use only
E	3.8-5.2	Last about 30 hrs (2 L/min)
D	1.5	Last about 11 hrs (2 L/min)
C	0.55	Last about 3 hrs (2 L/min)
Travelar	0.257-0.852	Depends on size

$1M^3$ = 1000 L

cylinder in clinical practice. To know this the following equation can be used-

$$\text{Remaining time (in hours)} = \frac{\text{remaining pressure (PSI)}}{200 \times \text{flow rate (Lit/min)}}.$$

Liquid oxygen containers

These are small in size, contain high amount of oxygen in a liquid form, give high purity oxygen, simple to carry. Their major disadvantage is their limited availability, high cost and spontaneous evaporation.

Oxygen concentrators

Fig. 3: Liquid oxygen container

These are electrically driven machines which take in normal air and concentrate oxygen to the required level up to 5ltr/min. these provide a long term solution to the patients who require prolonged oxygen therapy. They are relatively in expensive, one time investment, portable and easily available. Their draw backs are that they need continuous power supply, produce noise and vibration, machine failure, and give only up to 40% FiO_2.

While these are the sources of oxygen from where we get it, the "oxygen therapy devices" are the equipments through which this oxygen is delivered to the patient.

Oxygen Therapy Devices

These are broadly classified as

1) Variable performance devices and

Fig. 4: Oxygen concentrator

2) Fixed performance devices.

Variable performance devices[1,3] give uncontrolled oxygen therapy as their function is a coefficient of receivers respiratory efforts. Various subject and device factors influence their performance. They are

i) Subject factors

a) Inspiratory flow rate, which not only varies within each breath but attains a variable peak from breath to breath.

b) Duration of expiration and

c) Expiratory pause, these increase the oxygen concentration in storage capacity systems.

ii) Device factors

a) O_2 flow rate

b) Physical volume of the device

c) Vent resistance.

The subtle interplay of these factors result in unpredictable O_2 values in an individual rather than a true change in the state of lungs under treatment.

The variable performance devices may be functionally sub divided in to 3 types,

1) No capacity systems - nasal catheters and cannulae,

2) Small capacity systems - any device containing mask only. and

3) Large capacity systems – any device with a reservoir bag.

Nasal catheters and cannulae

these deliver oxygen directly in to the nose of the patient at a low flow rate. These generally deliver a FiO_2 of 24-50% depending upon the peak inspiratory flow rate (VI) and oxygen flow rate (VFO) such that

$$FiO_2 = 0.2093 + (VFO/VI).$$

They are less restrictive than masks, useful even in mouth breathers.

Their disadvantage is that high flow rates are uncomfortable to the patient and it can quickly dry the nasal mucosa.

Oxygen Masks

These are small capacity, variable performance devices. The functional apparatus dead space acts as a capacitor of the oxygen in this device. The cross sectional area and the leaks around the margins make it as a small capacity and variable performance device. They generally achieve a FiO_2 of 35-55%.

Mask with reservoir bag

The bag acts as a oxygen reservoir which is connected to the mask. These are also variable performance devices because their performance depends on 3 factors namely – fresh O_2 which can accumulate throughout the respiratory cycle, expired gas retained in the dead space and loss of fresh gas from leaks. Hence rebreathing masks give less FiO_2 than non rebreathing masks.

Fixed performance devices allow controlled (fixed and selectable) oxygen delivery. The essential feature of such devices is that they blow the oxygen mixture at patients in excess of their peak inspiratory flow rate. They operate on "venture principle", in which pure oxygen entrains a constant ratio of room air to produce a fixed concentration.

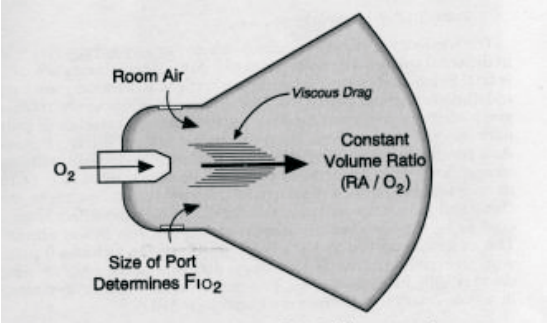
The oxygen delivery devices can also be classified as[1,4,5]

*Low flow systems – nasal cannula, nasal catheter.

*Reservoir systems – simple mask, partial rebreathing and non rebreathing masks.

*High flow systems – venture masks

Fig. 5: Ventury mask



*Enclosure systems – oxyhood, oxygen tent, incubators.

*Special modes – hyperbaric oxygen therapy and ECMO.

Oxyhood

An oxyhood is a clear plastic shell kept enclosing the infants head. FiO_2 depends upon gas flow, number of side ports closed, patient efforts. Generally they give a FiO_2 around 80-90% at 10-15 lit/min flow. They are ideal for newborns and infants up to 6 months of age.

Incubators

These are used usually for neonates and infants less than 3 months of age who are not on ventilators. It is an easy method of giving controlled O_2 therapy with combined use of a venture up to 40%. The disadvantage is it needs continuous monitoring, O_2 concentration can fall rapidly when opened, high flow rates such that comlete air change occurs at least 10 times per hour.

Oxygen tents

These are used in uncooperative children. There is no build up of heat. Complete air change is achieved 20 times per hour, and an FiO_2 of nearly 75% can be achieved. Their disadvantage is they require high oxygen flow rates, difficult patient monitoring and availability.

Hyperbaric oxygen therapy (HOT)

This technique works on the principle that at higher pressures (2.5 -3 Atm) the dissolved oxygen can be increased to nearly 5.6 ml/ 100ml of blood (normal 2ml). At rest the oxygen extraction by tissues is about 5ml/ 100ml of blood circulated. That means the O_2 supply can be met even in the absence of hemoglobin.

HOT is used for –treatment of air embolism, carbon monoxide poisoning, to enhance wound healing, for radiation necrosis and exceptional blood loss.

Hazards and complication of oxygen therapy[5,6,7]

Oxygen is a relatively benign drug, however it has some inharent hazards. They are classified as

1) Physiological – i) in preterm infants a PaO_2 of >80 mm Hg is linked with retinopathy of prematurity, ii) it can cause imbalance in systemic and pulmonary blood flow, iii) it can induce pulmonary fibrosis in paraquat poisoning and bleomycin intake, iv) inappropriate therapy causes persistant hypoxia or hyperoxia and v) persistant high FiO_2 can induce lung damage and surfactant inactivation.

2) Physical – the devices used may cause physical injuries to face, nose, lips etc.

3) Others – bacterial contamination is increased with humidifier systems, fire hazards are increased.

Even after this one should know the fact that "many patients die of hypoxia than due to the potential complications of oxygen therapy."

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