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Oxygen Therapy

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Abstract: **Oxygen therapy is a treatment providing more than 21% oxygen to the patients. It is necessary to take into account its indications, side effects and prescribing methods. Specific oxygen delivering devices are available and it is categorised into fixed and variable performance devices. Choice of these devices depends on condition of individual patients. Oxygen can be prescribed as uncontrolled oxygen therapy or controlled oxygen therapy which also depends on the disease state of the patients. Risks and benefits of oxygen should be balanced, however it should not be prevented in any crisis condition.**

Keywords: **Advantages, disadvantages, devices, oxygen therapy, risks, uses.**

I. INTRODUCTION

21% of our earth's atmosphere is oxygen. Oxygen is a colourless and odourless gas and first recognized by Joseph Priestley in 1771.[1]It has been used in our clinical practice for more than 200 years. It is essential for the functioning and survival of all body tissues and lack of oxygen for a few minutes can be fatal. It must be considered as a pharmacological agent with indications, benefits and side effects like any other drugs. Oxygen therapy is a treatment that provides the patient with extra oxygen (>21%). It is widely used in prehospital and hospital environments as well as domiciliary or long-term oxygen therapy. This short article includes oxygen manufacture and storage, practical uses of oxygen therapy, oxygen delivering devices, how to prescribe oxygen and risks of oxygen treatment.

II. OXYGEN MANUFACTURE AND STORAGE

99% or 99.5% pure oxygen is regarded as medical grade oxygen. It is manufactured by fractional distillation of liquefied air based on different boiling points of gases contained in the atmospheric air. After oxygen is manufactured, it can be stored as follows:

(i) Vacuum insulated evaporator (VIE):

When the gas becomes liquid form, it occupies a much smaller volume. Therefore, a large amount of oxygen can be stored in the form of liquid. A VIE is a container designed to store liquid oxygen.[2]The VIE system is used in large hospitals which have a pipeline system. It is the most economical way to store and supply oxygen.[4]

(ii) Oxygen cylinders:

Oxygen can be stored under pressure in cylinders. Oxygen cylinders are made of molybdenum steel and manufactured in different sizes (Table I). Size E cylinder is usually attached to the anaesthetic machine.[4]They are color-coded as black body and white shoulder in UK[1](Figure 1).

Table I. Oxygen cylinder sizes

Sizes	C	D	E	F	G	J
Capacity (litre)	170	340	680	1360	3400	6800

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Oxygen can also be produced by oxygen concentrator. It is a device which extracts oxygen from atmospheric air by using zeolite molecular sieve. Small or large concentrators are available to supply a single patient or for pipeline system.[4]

Figure 1. Oxygen cylinder

III. PRACTICAL USES OF OXYGEN THERAPY

(i) Hypoxia:

Hypoxia is a deficiency of oxygen at the tissue level. Hypoxaemia is deficiency of oxygen in arterial blood ($PaO_2 < 60$ mmHg). Hypoxia can be divided into 4 types:[2]

- ***Hypoxic hypoxia***

In this type of hypoxia, oxygen tension of arterial blood is reduced, eg. altitude, equipment error, drug overdose, asthma.

- ***Anaemic hypoxia:***

In this type of hypoxia, arterial oxygen tension is normal. However, amount of Hb available to carry oxygen or Hb function is reduced, eg. anaemia, carboxyhemoglobinemia, methemoglobinemia.

- ***Ischaemic hypoxia:***

In this category, arterial oxygen tension and Hb concentration are normal. Blood flow to the tissues is reduced and oxygen cannot be delivered to the tissues, eg. congestive heart failure, dehydration.

- ***Histotoxic hypoxia:***

Above all factors are normal in this type, however a toxic agent prevents the cells from using oxygen although oxygen is delivered to the tissues, eg. cyanide toxicity.

(ii) Pre-oxygenation:

If the patient is breathing room air, the oxygen store in functional residual capacity (FRC) is approximately 450 ml and it can be increased to 3000 ml with breathing 100% oxygen. As a result, there will be a rapid fall in oxygen saturation during apnoea (e.g. following induction of anaesthesia) if breathing room air. Pre-oxygenation means breathing 100% oxygen for three to five minutes through an anaesthetic circuit with a face mask firmly applied to the face. This will replace the nitrogen in the FRC with oxygen and also referred to as denitrogenation. The extra oxygen in the FRC can provide an essential store of oxygen for period of apnoea after induction. It is particularly essential for rapid sequence induction and difficult intubation.[5]

(iii) Postoperative oxygen:

Additional oxygen should be given to all patients for the first 10 min after general anaesthesia, as a result of hypoxaemia during the early recovery period. Postoperative hypoventilation is common due to the residual effect of anaesthesia, opioid analgesia, pain or airway obstruction. Prolonged oxygen therapy is required after operation in certain conditions such as hypotension, ischaemic heart disease, anaemia, obesity and shivering.[1]

(iv) Hyperbaric oxygen therapy:

Hyperbaric oxygen therapy means the patient is exposed to oxygen tension exceeding ambient barometric pressure. It is indicated in decompression sickness, gas embolism, gas gangrene and carbon monoxide poisoning.[3]

IV. OXYGEN DELIVERING DEVICES

There are two main types of oxygen delivering devices; fixed and variable performance devices.[2]

(i) Fixed performance devices:

By using fixed performance devices, patient receives a constant inspired oxygen concentration (FiO_2) and it does not depend on patient's ventilation. It is regarded as patient independent devices.

Examples of fixed performance devices are:

(a) High air flow oxygen enrichment devices (HAFOE devices) eg. Ventimask

(b) Head boxes for neonates

(a) HAFOE devices eg. Ventimask:

Ventimasks are colour coded (Figure 2) and it states the flow of oxygen in litres per minute required to deliver a specific inspired oxygen concentration. Holes on the Venturi device allow entrainment of room air by the Venturi principle. These holes also flush expired gas. Advantages of using Ventimask include very precise measurement of delivered oxygen and no rebreathing. However, the mask is hot and may irritate the skin. Oxygen concentration may lower by kinking the tubing.

Components of Ventimask[4]

- Body of the mask with holes
- Color-coded venturi device
- Corrugated tubing
- Adjustable head strap

Figure 2. Venturi mask

(b) Head box for neonates (Oxygen hood):

It is ideal for relatively short-term oxygen therapy for newborns and inactive infants. It cover only the head and oxygen is delivered into the box with 10-15 L/min to flush CO_2 (minimum flow 7L/min).[3]

(ii) Variable performance devices:

By using variable performance devices, the oxygen concentration delivered depends on patient minute ventilation, peak inspiratory flow rate and oxygen flow rate.[2]It is regarded as patient dependent devices.

Examples of variable performance devices are:

(a) Nasal cannula

(b) Simple face mask

(c) Mask with O_2 reservoir

(a) Nasal cannula:

It is ideal for long term oxygen therapy. It does not increase dead space and there is no rebreathing. Flow rate of 2-4 L/min is recommended as higher flow rate (>5L/min) can result in discomfort of the patient.[3]Advantages and disadvantages of nasal cannula can be seen in Table II.

Table II. Advantages and disadvantages of nasal cannula

Advantages	Disadvantages
1. Easy to use	1. Drying and irritation of nasal mucosa
2. Low-flow oxygen administration	2. Chance of nasal bleeding
3. Less restrictive than face mask	3. Sores around the external nares in long-term use
4. No increase in dead space	
5. More tolerable than oxygen mask	
6. Allow speech and eating/drinking	

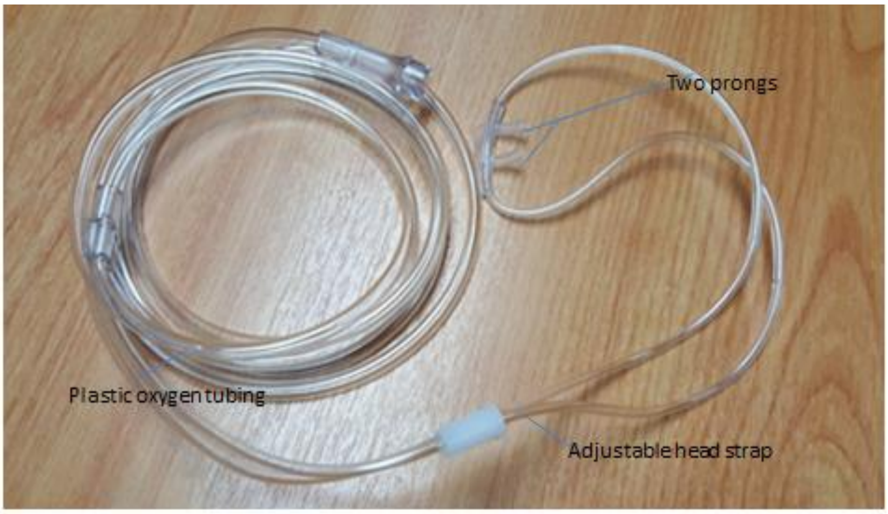

Figure 3. Nasal cannula

Components[4] (Figure 3)

- Adjustable head strap

- Two prongs

- Plastic oxygen tubing

(b) Simple face mask:

It is made of transparent plastic. Body of the mask serves as a reservoir for both oxygen and expired CO_2. It has a small dead space and can result in a small amount of rebreathing. Dead space depends on oxygen flow and patient's minute ventilation. Various sizes are available from paediatric to adult. It is indicated for patients who require higher levels of oxygen than cannulas eg. during medical transport, postanaesthesia care unit and emergency department.[3]

Components[4] (Figure 4)

- Body

- Vent holes

- Elastic band

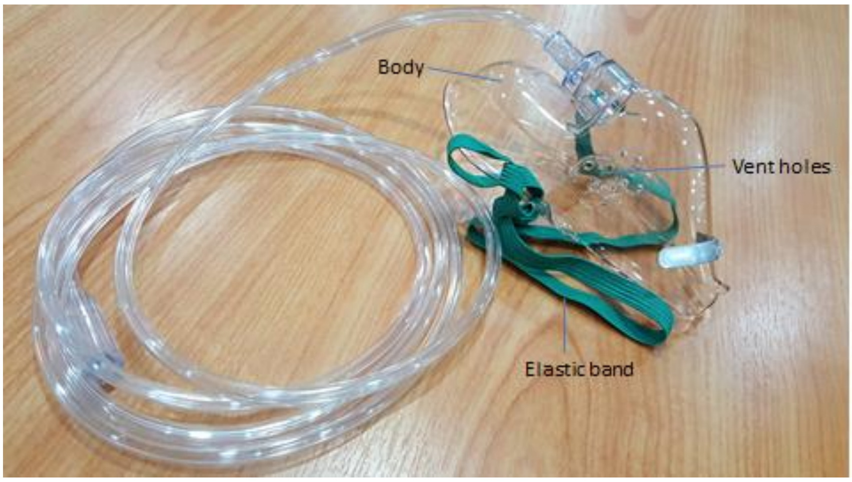

Figure 4. Simple face mask

Disadvantages of using simple face mask

- Patient complains of feeling of suffocation and poorly tolerated.

- Speech is muffled, eating and drinking are difficult.

Table (III) shows flow rates and approximate oxygen concentration delivered.[3,6]

Type	O_2 flow (L/min)	O_2 concentration (%)
Nasal cannulae	1	21-24
	2	23-28
	3	27-34
	4	31-38
Simple face mask	5-6	30-45
	7-8	40-60
Mask with O_2 reservoir (Rebreathing system)	10-15	70-80
Mask with O_2 reservoir (Non-rebreathing system)	10-15	95-100

(c) Mask with O_2 reservoir:

It is a standard face mask with addition of reservoir bag to increase the capacity of O_2 reservoir by 600 ml. There are two types of mask with O_2 reservoir; rebreathing system where there is no valve and gas can be exhaled in the initial phase of expiration returns to the reservoir bag and non-rebreathing systems where one-way valve is incorporated to prevent any exhaled gas from returning to the reservoir bag.[6]

V. HOW TO PRESCRIBE OXYGEN

(a) Uncontrolled oxygen therapy:

Oxygen is commonly prescribed freely to patients with cardiac or respiratory arrest, respiratory distress, asthma, hypotension or other critical conditions by using variable oxygen administration devices.

(b) Controlled oxygen therapy:

The oxygen concentration is prescribed using a HAFOE device in a small group of patients with chronic obstructive pulmonary disease (COPD). In those type of patients, CO_2 level is chronically raised and they depend on hypoxia to stimulate their respiration (hypoxic respiratory drive). High concentration O_2 can reduce respiration and cause respiratory depression. O_2 concentration should be started with 24-28% aiming to achieve PaO_2 >50 mmHg or SpO_2 85- 90%.[2]

VI. RISKS OF OXYGEN TREATMENT

There are both respiratory and non-respiratory toxicity due to the effects of oxygen therapy. It depends on patient susceptibility, FiO_2 and duration of therapy.[3]

(i) Fire hazard:

Oxygen supports combustion of other fuels.

(ii) Absorption atelectasis:

High concentrations of oxygen can cause atelectasis especially in dependant areas of the lungs.[2]When oxygen is the only gas being given, it is rapidly and completely absorbed from the alveoli and results in collapse (absorption atelectasis).[5]Nitrogen present in the air is absorbed more slowly and prevents the alveolus from collapsing.

(iii) Retinopathy of prematurity (ROP):

It is a neovascular retinal disorder and formerly termed retrolental fibroplasia. It is caused by vascular proliferation followed by fibrosis and retinal detachment leads to blindness. The low birth weight, very premature infant is at risk.[2]It is resolved in 80% of cases without visual loss. PaO_2 of 50-80 mmHg is recommended in premature infants receiving oxygen.[3]

(iv) Pulmonary toxicity:

Patients exposed to high oxygen levels for a prolonged period of time have lung damage. It depends on FiO_2 and duration of exposure. It is due to intracellular generation of reactive O_2 metabolites (free radicals) such as superoxide and activated hydroxyl ions, singlet O_2 and hydrogen peroxide, which can damage alveolar-capillary membrane. Pulmonary capillary permeability increases and leading to edema, thickened membranes and finally to pulmonary fibrosis.[3]Pulmonary fibrosis may occur after exposure to high concentration of oxygen for a week.[1]

(v) Depression of ventilation:

It is seen in COPD patients with chronic CO_2 retention who have hypoxic respiratory drive to breath. Increased arterial tension to normal can lose the hypercapnoeic stimulus to maintain ventilation resulting in hypoventilation in these patients.[3]

(vi) Hyperbaric oxygen toxicity:

Prolonged exposure of hyperbaric O_2 therapy can lead to pulmonary, optic and central nervous system toxicity. Symptoms of pulmonary toxicity include retrosternal burning, cough and chest tightness. It can cause narrowing of the visual fields and myopia in adults. Signs and symptoms of central nervous system toxicity include behaviour changes, nausea, vertigo, facial twitching and tonic-clonic zeizures.[1]

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VII. CONCLUSION

Oxygen is essential for all vital organs in our body and widely used in all medical specialities. It is the first drug to be given in any crisis condition. Different types of oxygen delivering systems are available and necessary to choose depending on condition of individual patients. As each drug has its own adverse effect, oxygen therapy also has some risks. However in any crisis condition, it is the lifesaving drug, therefore should never prevent oxygen since lifesaving is our first priority.

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