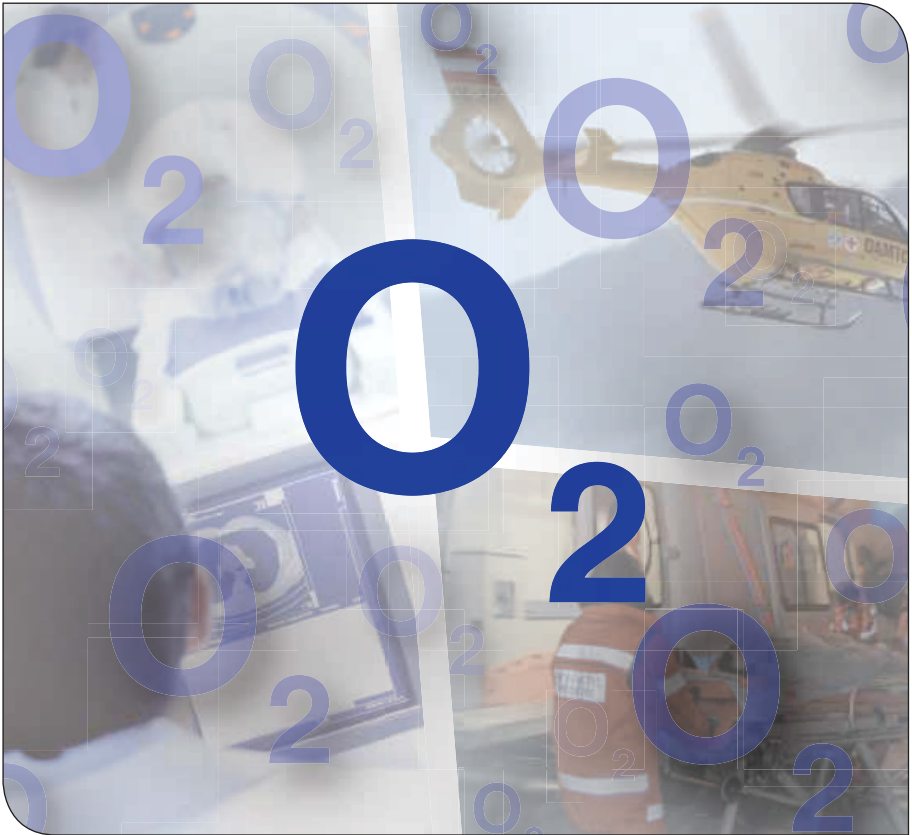


An Introduction to Oxygen Therapy



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Section 1: Oxygen and life

Introduction

The air around us contains about 21% oxygen as part of a mixture of other gases, mainly nitrogen. Man has evolved and adapted to live and work breathing this mixture. Oxygen is used in the power houses (the mitochondria) of the billions of living cells that make up the human body, to produce the essential fuel (ATP = Adenosine triphosphate) to ensure the vital function of the body. In the cells oxygen is converted to carbon dioxide which is exhaled through the lungs as part of breathing. The balance between the intake of oxygen and eliminating carbon dioxide is the essence of respiration itself.

While the concentration of oxygen present in air is capable of supporting a very wide range of demands from the body during rest and exercise under normal healthy conditions, if the heart and lungs become affected by disease or the body suffers trauma, additional oxygen beyond that available in the air may be required to ensure the continuity of supply to the cells. Not all body cells use oxygen at the same rate. Certain cells, such as the neurones in the brain use it at a very high rate and are very vulnerable if the supply of oxygen in the blood is reduced, a condition known as hypoxia.

Oxygen therapy (supplying extra oxygen) is required in situations where air alone is no longer sufficient to ensure the needs of the cells. The objective of this booklet is to describe in a simple way how oxygen is supplied to the body and the methods that are used to provide higher concentrations of the gas to patients who are still breathing. It does not deal with the situation of a patient who is breathing inadequately or has stopped breathing altogether. These situations are known respectively as respiratory failure and respiratory arrest and are the subject of other booklets in this series (*reference: LIT/AV2591 and 504-3087 "When Breathing Fails"*)



Oxygen levels in the body

Oxygen partial pressures	kPa	mm Hg
• Dry atmospheric gas	21.1	159
• Inspired tracheal gas	19.8	149
• Alveolar gas	14.7	110
• Arterial blood	13.3	100
• Mixed venous blood	5.3	40

Box 1: the oxygen cascade. The partial pressure of a component of a gas mixture is the pressure it would exert if it were present alone (eg in the alveolus). Partial pressure rather than concentration, is used conventionally in physiology to express oxygen levels.

When we breathe, air enters the lungs via a series of connecting structures including the bronchi, which are collectively known as the respiratory tree. The concentration of oxygen found at the various stages of the respiratory tree and in the blood beyond the lungs, decreases steadily so that the concentration found in the air sacs of the lungs where oxygen transfer takes place between the gas and the blood (the alveoli) is only about two thirds of that found in the air. The normal process of breathing ensures that oxygen is carried down to the alveoli during inhalation and that the carbon dioxide is eliminated during exhalation. This process is called external respiration. The transport of oxygen from the lungs into the blood and to the cells of the body and the return of carbon dioxide to the lungs is called internal respiration (see Figure 2), for more on breathing and respiration see *Pneupac* booklet LIT/AV2591.

Oxygen carriage in the blood

Oxygen physically dissolved in the blood is not nearly sufficient to support the respiratory requirements of the body cells. Most of the oxygen contained in the blood is carried on a pigment called haemoglobin, which gives the blood its characteristic colour, and which has the ability to carry and release far more oxygen than is possible by solution alone. The key parameter, which describes the loading of oxygen on the haemoglobin (Hb) is the saturation, which is the percentage of oxygen actually in the blood compared with the maximum possible. The saturation of the blood can be monitored non-invasively using a pulse oximeter.

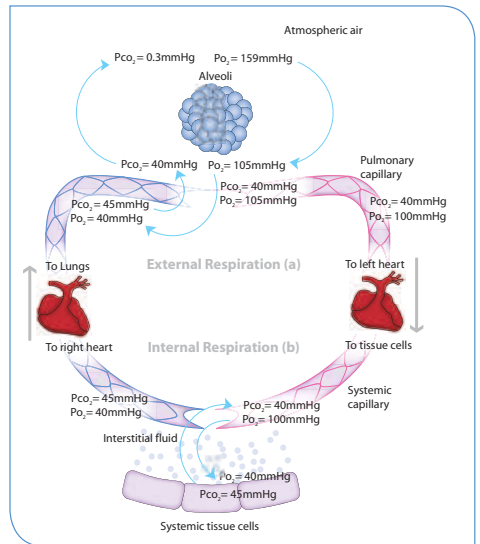


Figure 2 External and Internal respiration

What is a Pulse oximetry device?

A pulse oximeter is a non-invasive medical device that indirectly measures the oxygen saturation level of a patient's blood (as opposed to measuring oxygen saturation directly through a blood sample). Using technology that utilises the light absorptive characteristics of haemoglobin and the pulsatile nature of blood flow through the arteries, pulse oximetry painlessly provides a general indication of oxygen delivery to the tissues in a variety of circumstances such as surgery, procedures involving sedation, mechanical ventilation, sleep apnea and other medical conditions.



The following features of the Hb dissociation curve shown in figure 1 are important:

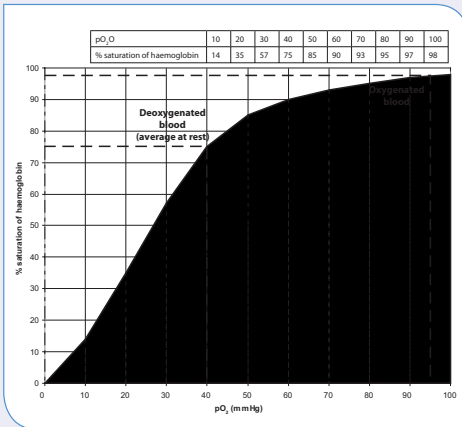


Figure 1

1. The relationship between the partial pressure of oxygen in equilibrium with Hb and the degree of saturation is not linear. Thus between 80 and 100 mm the saturation varies between about 95 and 97%. In a normal healthy man or woman approximately 97% of oxygen is carried to the tissues combined with haemoglobin, while 3% of oxygen is transported in a dissolved state in the blood plasma. While the theoretical partial pressure of oxygen in the alveoli when breathing air is 104 mm the value in arterial blood is always slightly less than this due to 'shunting' or mixing of blood that has not been oxygenated. This may be because of normal physiological reasons or as a result of alveoli that are not functioning correctly. Shunting is important to understanding the rationale behind oxygen therapy and is discussed further in box 3.
2. At a saturation of 75% the partial pressure of the oxygen in the blood is 40 mm. This is a measure of the remaining oxygen in the blood returning to the lungs through the veins (venous blood). It should be noted that in certain circumstances such as extreme exercise it is possible to desaturate the Hb in the blood further and extract more oxygen for the tissues.
3. The total oxygen content of the blood is the sum of that carried by the Hb plus that carried in solution. The normal values of oxygen content for arterial blood and venous blood are 19.5 ml/dL and 4.7 ml/dL respectively. Note that the body usually only extracts about 25% of the oxygen carried by haemoglobin. The normal resting consumption of oxygen by the body is 250 ml/minute which produces 200 ml of carbon dioxide. In conditions of exercise oxygen consumption increases and the extraction of the oxygen from Hb is greater than at rest but the proportion of CO₂ produced is about the same.
4. Extraction of oxygen from Hb can be made more easy or difficult depending on the position of the dissociation curve. If the blood is more acid for example there is a shift of the curve to the right in relation to the axes which enables the delivery of more oxygen (increased desaturation). Conversely if the blood is more alkaline extraction of oxygen is more difficult. The position of the Hb curve is described in terms of the p50 value which is the partial pressure of oxygen around the Hb for 50% saturation.

Why arterial oxygen content can fall: the requirement for oxygen therapy

The normal transfer of oxygen from the gas in the alveoli to the blood is affected by

- (1) the continued process of breathing which ensures that gas enters and leaves the lungs and
- (2) the characteristics of the walls of the alveoli across which the oxygen and carbon dioxide diffuse.

If either of these factors changes, respiratory failure is said to occur. This ultimately leads to a reduction of oxygen in the body (hypoxia).

There are two recognised types of respiratory failure;

Type 1 is when transmission of oxygen across the alveolar membrane is impaired. This can occur with the build up of fluid in the lungs as

a result of heart failure or from toxic inhalation or with the early stages of pneumonia and or with the actual thickening of the walls as in pulmonary fibrosis. In Type 1 respiratory failure the arterial oxygen is reduced but the carbon dioxide level is normal or low.

Type 2 respiratory failure occurs when the process of breathing is impaired and there is reduced ventilation of the lungs. This can occur with conditions such as chronic bronchitis, muscle weakness and with sedation of the controlling respiratory centre in the medulla of the brain.

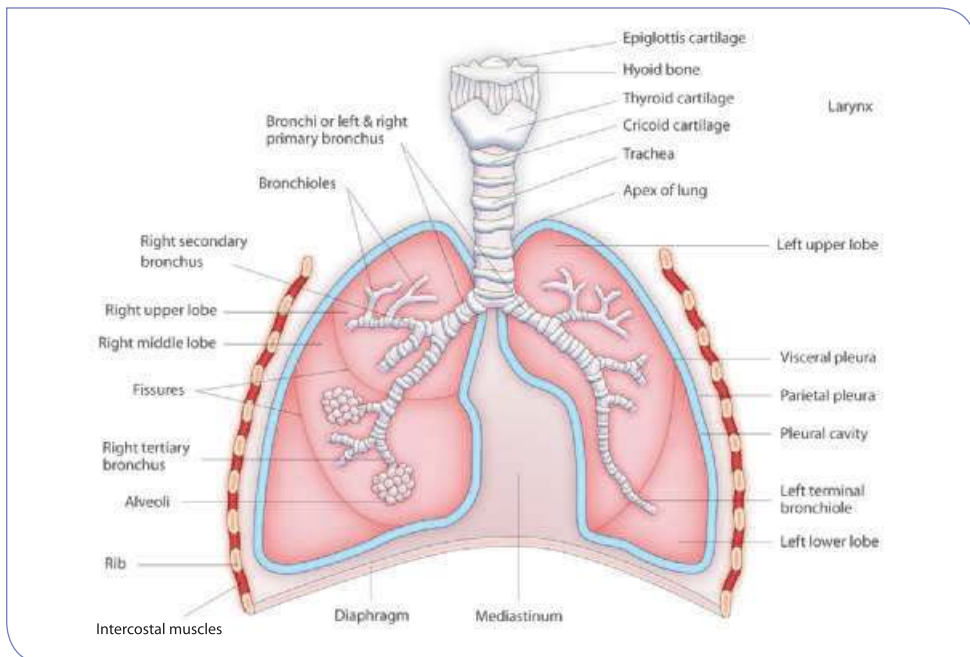


Figure 1 General Anatomy of the Lungs

SECTION 2: Options for oxygen therapy

In Section 1 of this booklet we have considered the normal role of oxygen in the body and how this can change with disease and injury. This section considers the responses available and how to give oxygen to a patient who is still breathing. The management of patients who are breathing insufficiently or not at all is the subject of a different booklet (*Pneupac LIT/AV2591*)

Assessment of oxygenation:

- Evidence of trauma and hypovolaemic shock
- Breathing: depth and form
- Cyanosis (look at mucus membranes and nail beds)
- Pulse oximetry: to measure arterial oxygen saturation

1 Giving oxygen

The simplest way to administer higher concentrations of oxygen than in the surrounding air is to deliver a flow of oxygen at atmospheric pressure at a rate of 6 – 8 litres/minute to a lightweight plastic mask covering the mouth and nose (the pharyngeal mask). This is the commonest form of oxygen therapy used in both, prehospital and hospital practice (see pictures below). The actual concentration delivered to the patient depends on :

1. the flow of oxygen
2. the tightness of fit of the mask on the face
3. the type of mask used

In emergency, up to 100% oxygen can be

delivered using a mask that has no ventilation holes. This device does not mix oxygen with air from the outside and so the concentration can approach 100%. Such a concentration is suitable over short periods for persons who are acutely hypoxic, who have exacerbations of previous problems or are hypoxic due to trauma or haemorrhage. It is also used for asthmatic patients who are in an acute crisis. 100% oxygen is not usually administered for long period particularly in infants where it can cause damage to the eyes.



2 What can free flow oxygen therapy achieve?

Free flow oxygen therapy can do the following:

1. correction of hypoxia when the patient is still breathing adequately but there is interference with the transfer of oxygen through the alveolar wall into the blood (type 1 respiratory failure)
2. correction of hypoxia with type 2 respiratory failure with hypercapnia (eg in chronic obstructive airways disease). Care must be taken if the patient is reliant on hypoxic drive to continue breathing. (See box)
3. correction of hypoxia due to lung shunt where blood is passing through sections of the lung that are not being ventilated. It should be noted that with large degrees of shunt (over 30%) the oxygen deficit cannot be overcome even when breathing 100% oxygen.

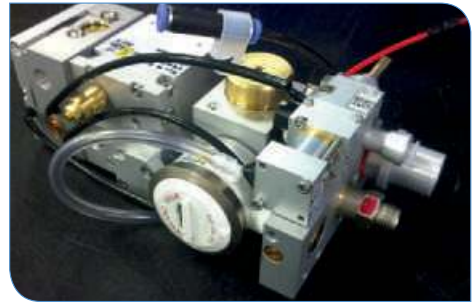
Box 2: Hypoxic drive and oxygen therapy

Breathing is controlled normally by the level of carbon dioxide in the blood. Special receptors in the medulla of the brain detect when the levels are increased and stimulate breathing accordingly to correct the situation. However in patients who have had high levels of blood CO_2 for some time (eg in chronic bronchitis – chronic obstructive airways disease (COAD)) breathing is stimulated by oxygen sensors in the large arteries as a secondary system to ensure that breathing continues.

However, if the blood oxygen level is suddenly raised by breathing high concentrations of oxygen, the hypoxic drive through the oxygen receptors may cease to function and breathing can stop. For this reason oxygen delivered in free – flow therapy to a patient with COAD is usually titrated using a mask that admits a variable amount of air at a set oxygen flow (a venturi mask) so that the best compromise between blood oxygenation is achieved at the lowest inspired oxygen concentration. All patients who are receiving free – flow oxygen must be checked to make sure that their breathing rate and depth does not diminish, indicating possible impending respiratory failure.

4 Demand valve delivery of oxygen

As the name suggests, with free flow oxygen therapy the flow of gas is continuous during inspiration and continues during expiration. An alternative method of delivery is to use a demand valve system. Here oxygen is only delivered when the patient takes a breath and switches off during expiration so that gas wastage is minimised. The valve operates when it detects a negative pressure of 2 cm water generated by the patient's inspiration. The gas is delivered at atmospheric pressure and is not therefore a ventilation system. Some portable ventilators also have a demand oxygen delivery system linked to mandatory ventilation which operates if the patient has adequate spontaneous ventilation and does not require ventilation assistance. (See *Pneupac* booklet #003)



Demand valve: this is fitted to ventilators such as VR1 or Parapac or can also be stand alone as in the Inhalation Analgesia kit shown

5 Continuous positive airway pressure (CPAP)

Free flow oxygen is delivered at the pressure of the surrounding atmosphere. However if the pressure of the gas delivered to the patient is above atmospheric pressure the type of oxygen therapy delivered is known as Continuous Positive Airway Pressure (CPAP). The experience for the patient breathing CPAP has been compared to breathing while facing into the wind in a fast moving open – top vehicle. CPAP is used clinically to improve oxygenation in special situations where free flow oxygen is not adequate or appropriate.

CPAP does the following things:

1. the applied positive pressure makes the work of inspiration easier.
2. it makes the work of expiration (usually a passive action in healthy subjects) harder but helps to open up (recruit) alveoli in the lungs that may be shut down and therefore shunted.
3. in conditions like congestive heart failure where there is a build up of fluid in the lungs CPAP helps to push the fluid back from the alveoli into the circulation and thus improves oxygen transfer to the blood. CPAP may be used in this way as an emergency treatment for heart failure in the pre-hospital setting. It is also used in the same way inside the hospital.
4. CPAP may also be used in the home setting to treat a condition called sleep apnoea where the upper airway in the pharynx becomes blocked by the soft palate. The positive pressure from CPAP is said to hold the airway open.



CPAP on patient in ambulance

How CPAP is used

In its simplest form CPAP is generated using a special circuit into which free – flow oxygen at a high rate is introduced. To ensure that the pressure being delivered to the patient is positive CPAP must be delivered through a closed and tightly – fitting pharyngeal mask.

Safety checks for CPAP

Before starting CPAP in any patient the following rules must be followed:

1. the patient must be fully – conscious and sufficiently alert to understand what is happening and the sensations they will feel when breathing.
2. there must be no indication of any failure in breathing and ventilation.
3. the patient must be able to tolerate the close fitting mask without a sense of claustrophobia.

Observation of patients on CPAP

Patients on CPAP must be closely observed for any signs of distress or respiratory failure.

CPAP does NOT support ventilation and is not a ventilation mode as found on ventilators, (refer to booklet #003) Any patient who is on CPAP must be observed closely for possible apnoea (stopping breathing) . In the case of infants and young children an apnoea alarm which detects failure to breathe must be used



CPAP kit for paraPAC plus

Conclusions

This booklet has provided a simple introduction to oxygen therapy delivered in a free flow form and also as continuous positive pressure. These forms of oxygen treatment are suitable for patients who are suffering from hypoxia from a number of reasons but who are still breathing. Patients who are not breathing adequately or at all must have their airway secured and be ventilated. Free flow oxygen, CPAP and IPPV can be regarded as a spectrum of options that are available in prehospital and hospital practice to ensure the continued delivery of oxygen to the body. Oxygen has been in use in medicine for over 150 years but the value of administration remains undiminished. It is important that the basic facts surrounding its value and use are understood by all those who have a responsibility for the care of the sick and injured.



PneuPac paraPAC plus offering all forms of Oxygen delivery described in this text:

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