

[Newborn Care Manual: Contents](#)

26-1 WHY DOES THE BODY NEED OXYGEN?

Energy for all the vital functions of the body is obtained by either aerobic or anaerobic metabolism:

1. AEROBIC METABOLISM releases energy from carbohydrates, proteins and fats by the process of oxygenation. Aerobic metabolism is used by most cells, as it produces large amounts of energy for prolonged periods of time, but requires the presence of oxygen.
2. ANAEROBIC METABOLISM, in contrast, does not need oxygen but is far less efficient as it produces small amounts of energy and only functions for short periods of time.

In the body, oxygen is carried by red blood cells from the lungs to all the other organs. When loaded with oxygen the red blood cells are red in colour and as a result the infant's tongue appears pink. However, if the red blood cells carry too little oxygen they become blue in colour and the tongue appears cyanosed.

26-2 HOW IS THE AMOUNT OF OXYGEN IN THE ATMOSPHERE MEASURED?

The amount of oxygen in the atmosphere is determined by measuring its partial pressure or concentration:

1. PARTIAL PRESSURE of oxygen is measured in kilopascals (kPa) or millimetres of mercury (mm Hg).
2. CONCENTRATION of oxygen is given as a percentage (e.g. 40%) or a fraction (e.g. 0,40).

The concentration of oxygen in room air is usually called the FRACTION OF INSPIRED OXYGEN, and abbreviated to FiO_2 . For example, the FiO_2 is normally 0,21 (i.e. 21%). It is preferable to speak about the fraction rather than the percentage of oxygen in inspired air as the latter is often confused with the percentage oxygen saturation in the blood.

FiO_2 = FRACTION OF INSPIRED OXYGEN

26-3 HOW MUCH OXYGEN IS PRESENT IN ROOM AIR?

The atmosphere of earth consists of a mixture of many gases such as nitrogen, oxygen and carbon dioxide. Oxygen forms 0,21 (or 21%) of the gas in the atmosphere. This is true, both at sea level and at high altitudes, and is adequate to meet the needs of aerobic metabolism in adults and newborn infants.

**** The atmosphere exerts a pressure as demonstrated by the collapse of a soap bubble. Twenty one percent of the total pressure in the atmosphere, which is 100 kPa (760 mm Hg) at sea level, is produced by oxygen. Therefore, the partial pressure of oxygen in the atmosphere is 21% of 100 kPa (760 mm Hg), which is 21 kPa (160 mm Hg).*

26-4 HOW DO YOU DETERMINE THE AMOUNT OF OXYGEN IN THE BLOOD?

1. This can be roughly assessed CLINICALLY as the infant appears peripherally and centrally cyanosed (blue) if there is not enough oxygen in the red cells. This clinical method is often inaccurate and should, whenever possible, be confirmed by measuring either the partial pressure or the saturation of oxygen in arterial blood.
2. In a laboratory the partial pressure of oxygen can be measured accurately in a sample of arterial blood using a machine called a BLOOD GAS ANALYSER, which measures the pH and concentration of oxygen and carbon dioxide. The partial pressure of oxygen in venous or capillary blood is usually not used as it does not reflect accurately the amount of oxygen reaching the tissues.
3. At the bedside the saturation of oxygen in arterial blood can be measured with a SATURATION MONITOR (i.e. PULSE OXIMETER), which simply clips onto the infant's hand or foot and measures the oxygen saturation through the skin.

The use of a saturation monitor is discussed in skills workshop 26 of this PEP manual.

*** The saturation monitor determines the saturation of oxygen in the arterial blood by assessing the colour of the red cells in the arteries. The red cell colour is determined through the skin. This does not require a sample of blood. Capillary blood can be used to measure the partial pressure provided that the puncture site (e.g. heel) is warmed and the blood allowed to run without squeezing.

26-5 HOW MUCH OXYGEN IS NEEDED BY THE NORMAL INFANT?

1. Normally a FiO_2 of 0,21 in the inspired air (i.e. 21% oxygen concentration in the air that is being breathed in) is sufficient to produce a partial pressure of oxygen in the arterial blood of 8-10 kPa (60-75 mm Hg). The partial pressure of arterial oxygen is referred to as the PaO_2 . A PaO_2 of 8-10 kPa (60-75 mm Hg) is normal and adequate to load the haemoglobin in the circulating red blood cells with oxygen.

PaO_2 = PARTIAL PRESSURE OF OXYGEN IN ARTERIAL BLOOD
 SaO_2 = SATURATION OF OXYGEN IN ARTERIAL BLOOD

2. Normally the haemoglobin in arterial blood is almost fully loaded with oxygen. The degree of saturation of arterial blood with oxygen is referred to as the SaO_2 . At a FiO_2 of 0,21 the SaO_2 in a newborn infant is normally 86-92%.

NORMAL PaO_2 = 8-10 kPa (60-75 mm Hg) AND NORMAL SaO_2 = 86-92%

*** The SaO_2 is determined by the PaO_2 and the haemoglobin's ability to take up oxygen. The SaO_2 increases in a linear manner as the paO_2 rises until the SaO_2 reaches 90%. Thereafter there is a poor correlation between the two measurements. This explains why a SaO_2 above 90% is potentially dangerous as the PaO_2 may be very high.

26-6 WHEN DOES AN INFANT NEED EXTRA OXYGEN?

If the PaO_2 falls below 8 kPa (60 mm Hg) and the SaO_2 falls below 86%, the red cells will not be adequately loaded with oxygen. The infant will now appear cyanosed and the cells of the body will not receive enough oxygen for aerobic metabolism. Therefore, extra oxygen is needed in the inspired air (i.e. a FiO_2 of more than 0,21) if:

1. The infant has central cyanosis (a blue tongue).
2. The PaO_2 drops below 8 kPa (60 mm Hg).
3. The SaO_2 falls below 86%.

26-7 IS TOO LITTLE OXYGEN DANGEROUS?

Yes. If the cells of the body do not receive enough oxygen they can be damaged or die. Without adequate oxygen, cells are forced to change from aerobic to anaerobic metabolism. This markedly reduces the amount of energy the cells can produce. Toxic substances, such as lactic acid, are also produced as a by-product of anaerobic metabolism. This causes a metabolic acidosis. The cells of many organs, but particularly the brain, are affected by these metabolic changes.

TOO LITTLE OXYGEN IN THE BLOOD CAN CAUSE BRAIN DAMAGE

26-8 WHEN SHOULD YOU GIVE AN INFANT EXTRA OXYGEN?

1. During resuscitation after delivery or in the nursery.
2. When there is respiratory distress due to conditions such as hyaline membrane disease, pneumonia and meconium aspiration.
3. When the infant has central cyanosis.
4. When the PaO_2 is below the normal range (less than 8 kPa or 60 mm Hg).
5. When the SaO_2 is below the normal range (less than 86%).

If the central cyanosis is not corrected when extra oxygen is given, it is essential to provide some form of artificial ventilation.

26-9 WHICH INFANTS DO NOT NEED EXTRA OXYGEN?

1. Infants with normal Apgar scores at birth. Do not give oxygen to infants who do not need resuscitation.
2. Infants with peripheral but not central cyanosis. If there is peripheral cyanosis only, the cause is usually cold hands and feet with poor perfusion, rather than hypoxia.
3. Infants with recurrent apnoea. They should only be given oxygen during resuscitation and not once spontaneous respiration has started.
4. Small, preterm infants with a normal PaO₂ and SaO₂.

ONLY GIVE EXTRA OXYGEN WHEN THERE IS A CLINICAL INDICATION

26-10 WHEN INDICATED, HOW MUCH OXYGEN DO YOU GIVE?

The FiO₂ should be increased until:

1. Central cyanosis is corrected (the tongue is pink).
2. The PaO₂ is 8-10 kPa (60-75 mm Hg) or SaO₂ is 86-92%.

The required FiO₂ to keep different infants pink may vary from 0,22 to 1,0. For example, an infant with severe lung disease may need a FiO₂ of 0,9 while another with mild lung disease may need only 0,25 to achieve a normal PaO₂ and SaO₂.

26-11 CAN YOU GIVE TOO MUCH OXYGEN?

Yes. If the FiO₂ is increased too much, the PaO₂ and SaO₂ will rise above the normal range. If the PaO₂ is above 10 kPa (75 mm Hg) or SaO₂ above 90%, the excessive amount of oxygen in the blood may damage the infant.

If a particular infant needs an FiO₂ of 0,35 to give a normal PaO₂ and SaO₂, increasing the FiO₂ to 0,50 will not help the infant any more and may be dangerous. Therefore, do not give oxygen unless it is needed.

In an emergency, such as resuscitation, a FiO₂ of 1,0 (100% oxygen) should be safely given for as short a time as possible. Giving oxygen can be dangerous when it is not required.

TOO MUCH OXYGEN IS DANGEROUS AS IT MAY DAMAGE THE INFANT

26-12 WHEN IS THE CONCENTRATION OF INSPIRED OXYGEN TOO HIGH?

Any FiO₂ that increases the PaO₂ or SaO₂ above the normal range is too high. It is impossible to tell by clinical examination alone that the FiO₂ is too high. The risk of oxygen damage is determined by the PaO₂ or SaO₂ and not by the FiO₂. A high FiO₂ is not dangerous if the PaO₂ or SaO₂ are normal (e.g. with severe respiratory distress). A high FiO₂ is most dangerous if there are no lung or heart problems, e.g. oxygen given to healthy preterm infants during transport.

26-13 WHAT ARE THE DANGERS OF TOO MUCH OXYGEN IN THE BLOOD?

1. If the PaO₂ is too high, the retina of the infant's eyes can be damaged causing RETINOPATHY OF PREMATURITY. If a very high FiO₂ is needed to maintain a NORMAL PaO₂ and SaO₂, the retina is not likely to be damaged. Therefore, it is the raised PaO₂ and not the increased FiO₂ that causes retinopathy. The longer the period during which the PaO₂ is too high, the greater is the risk of retinopathy.
2. A high FiO₂ for a long time, especially if the infant is intubated and on a ventilator, may damage the alveoli and small bronchi of the lung resulting in BRONCHOPULMONARY DYSPLASIA. This condition is not common, but is difficult to prevent.

A HIGH PaO₂ IN A PRETERM INFANT MAY CAUSE RETINOPATHY OF PREMATURITY**26-14 WHAT IS RETINOPATHY OF PREMATURITY?**

The immature blood vessels in the retina of preterm infants constrict (go into spasm) when exposed to a high PaO₂. This causes retinal ischaemia and haemorrhage with healing by fibrosis. This important eye problem is called retinopathy of prematurity. Mild degrees of retinopathy recover and vision is not affected. However, severe retinopathy with a lot of fibrosis causes a condition known as retrolental fibroplasia which can permanently impair vision and result in blindness.

The risk of retinopathy is greatest in the most preterm infants under 32 weeks gestation. At term the risk of oxygen toxicity to the retina is much less. Retinopathy is diagnosed by examining the eye with an ophthalmoscope.

26-15 HOW CAN YOU PREVENT RETINOPATHY OF PREMATURITY?

Most cases of retinopathy can be prevented by adjusting the FiO₂ so that the PaO₂ and SaO₂ are within the normal range. If these investigations are not available, give just enough oxygen to correct central cyanosis, i.e. just enough to keep the tongue pink.

**** Unfortunately the cause of retinopathy is not fully understood and some very immature infants may still get eye damage despite careful oxygen control. Infants of less than 32 weeks gestation should be screened for retinopathy at 6 weeks by direct fundoscopy.*

26-16 WHAT IS A SAFE CONCENTRATION OF INSPIRED OXYGEN?

No FiO₂ above 0,21 can be regarded as safe unless the PaO₂ or SaO₂ are measured and found to be in the normal range. Even a slightly raised FiO₂ in an infant with normal lungs will give a high PaO₂ and SaO₂. An increased FiO₂ is most dangerous in a preterm infant with recurrent apnoea but no respiratory distress, as the PaO₂ can become very high.

26-17 HOW CAN YOU SAFELY ADMINISTER OXYGEN?

As there are dangers in giving too much or too little oxygen, the following principles must be followed to ensure that oxygen administration is safe:

1. Usually a FiO₂ of 1,0 (100% oxygen) is only given for a short time during resuscitation. At all other times the FiO₂ must be matched to the infant's needs.
2. The FiO₂ must be adjusted to give a PaO₂ of 8-10 kPa (60 -75 mm Hg) or a SaO₂ of 86-92%.
3. If monitoring and laboratory facilities are not available, give just enough oxygen to correct central cyanosis. This clinical assessment is not accurate, however, so it is essential to determine the PaO₂ or SaO₂ as soon as possible.
4. The easiest method of monitoring oxygen therapy is with a saturation monitor to measure the SaO₂ continuously. Otherwise the PaO₂ must be measured, at least every 6 hours.
5. Never give oxygen therapy unless it is indicated. Stop the oxygen therapy as soon as it is no longer needed.

26-18 SHOULD YOU HUMIDIFY OXYGEN?

Yes. Oxygen should always be humidified and preferably also be warmed. Oxygen direct from a cylinder is very dry and cold. Dry oxygen irritates the airways while cold oxygen will drop the infant's temperature.

26-19 HOW SHOULD YOU CONTROL THE CONCENTRATION OF OXYGEN GIVEN?

The best way to control the FiO₂ is with an AIR-OXYGEN BLENDER. A blender accurately mixes pure oxygen with medical air to give the required FiO₂.

If a blender is not available, a VENTURI should be used. Some venturis mix pure oxygen with room air to give any required FiO_2 while others only give a fixed FiO_2 (e.g. 40%). The flow rate must NOT be used to control the concentration of oxygen given as it is far too inaccurate.

**** A venturi is a simple apparatus that uses a jet of oxygen to suck in a fixed amount of room air. The resultant mixture of gases gives a known percentage of oxygen.*

The use of an air-oxygen blender and venturi is explained in skills workshop 26 of this PEP manual.

26-20 WHAT FLOW RATE OF OXYGEN INTO A HEADBOX IS BEST?

When oxygen is given into a headbox, either directly or via a blender or venturi, the flow should be at least 5 litres per minute to prevent carbon dioxide accumulation. It is also very difficult to control accurately the FiO_2 by altering the flow rate when low rates are used. Alternately a high flow rate, such as 10 litres, wastes oxygen and cools the infant. With few exceptions, a flow rate of 5 litres per minute is best.

26-21 SHOULD THE OXYGEN CONCENTRATION BE MONITORED?

Yes. The concentration of inspired oxygen should, whenever possible, be measured with an OXYGEN MONITOR. This is the most accurate way of knowing what concentration of oxygen the infant is breathing. If an oxygen monitor is not available, the concentration of oxygen set on the air-oxygen blender or venturi is a good guide provided that the flow rate is 5 litres per minute or more.

The use of an oxygen monitor is discussed in skills workshop 26 of this PEP manual.

26-22 WHAT METHODS CAN YOU USE TO ADMINISTER OXYGEN?

1. Oxygen is most commonly given into a PERSPEX HEAD BOX. This is the best method of administering oxygen to most infants as it is a simple, cheap and highly effective method. A blender or venturi should be used.
2. Oxygen may be given via NASAL PRONGS when continuous positive airways pressure is needed. This is particularly useful in infants with respiratory distress.
3. An ENDOTRACHEAL TUBE is used for most infants receiving oxygen via a ventilator. The oxygen must be warmed and humidified.
4. At resuscitation oxygen is given via the FACE MASK of a resuscitator (bag and mask) or by endotracheal tube.

26-23 WHAT METHODS SHOULD NOT BE USED TO ADMINISTER OXYGEN?

1. Oxygen should not be given directly into a closed incubator as this method is wasteful, high concentrations cannot be reached and the concentration of oxygen drops every time an incubator port is opened.
2. Gastric oxygen via a nasogastric tube is valueless and dangerous.
3. Dry, unhumidified oxygen should not be given except for a short period in an emergency.
4. An oxygen flow meter alone, without a blender or venturi, should not be used to control the FiO_2 unless an oxygen monitor is also used. It is very difficult to control the FiO_2 with a flow meter alone and carbon dioxide may accumulate if the flow is too small.
5. Giving 100% oxygen via a cardboard cup is extremely dangerous as it is almost impossible to control the FiO_2 accurately. This method should be used as the last resort only.

IT IS BEST TO GIVE HEAD BOX OXYGEN VIA A BLENDER OR VENTURI

26-24 HOW LONG SHOULD AN INFANT RECEIVE OXYGEN?

Only as long as it is required to prevent central cyanosis and maintain a normal PaO_2 and SaO_2 . Whenever possible the FiO_2 should be reduced. Stop as soon as possible. The time that oxygen is required varies widely from one infant to another.

26-25 ARE FLUCTUATIONS IN THE OXYGEN CONCENTRATION IMPORTANT?

Yes. Even small fluctuations in the FiO_2 may cause a change in the PaO_2 and SaO_2 . With the correct equipment a stable FiO_2 can be maintained.

26-26 HOW RAPIDLY SHOULD YOU REDUCE THE OXYGEN CONCENTRATION?

The FiO_2 must never be reduced suddenly in a single big step. Instead it should be reduced in small steps of 0,10 (10%) at a time. A sudden, large drop in FiO_2 may cause severe hypoxia and collapse.

**** Flip-flop is the name given to the clinical situation where a sudden, large drop in the FiO_2 causes a dangerous drop in the PaO_2 with collapse and sometimes death. Increasing the FiO_2 back to the original level fails to correct the cyanosis. This is because of the development of pulmonary hypertension with a right to left shunt in response to the low PaO_2 .*

NEVER REMOVE AN OXYGEN DEPENDENT INFANT FROM OXYGEN, EVEN FOR A SHORT PERIOD OF TIME

26-27 WHAT EQUIPMENT DO YOU NEED TO GIVE OXYGEN SAFELY?

1. Source of pure (100%) oxygen. Either piped or cylinder oxygen is usually use. The cylinder must have a reducing valve and a gauge that measures the amount of gas present.
2. Plastic tubing.
3. Oxygen flow meter.
4. Preferably medical air. Either piped or from a cylinder.
5. Preferably an oxygen-air blender.
6. Venturi if medical air or blender is not available.
7. Humidifier.
8. Perspex head box or nasal prongs.
9. Preferably an oxygen monitor.
10. Preferably a blood gas analyser or saturation monitor.

26-28 IS IT SAFE TO USE AN OXYGEN CONCENTRATOR?

In areas where piped or bottled (cylinder) oxygen is not available, an oxygen concentrator can be used to concentrate oxygen from room air. The highest percentage of oxygen available from a concentrator is only about 40%.

CASE PROBLEMS**CASE 1**

A preterm infant is nursed in a closed incubator in room air. The doctor asks that the infant's PaO_2 be measured. When this is found to be low, she starts extra oxygen into a head box. The nurse is then asked to record the FiO_2 and SaO_2 .

1. How much oxygen is present in room air?

There is 21% oxygen in room air. Nitrogen forms most of the air we breathe.

2. What does PaO_2 mean?

PaO_2 stands for the partial pressure of oxygen in arterial blood, i.e. how much oxygen is in the blood. This is measured as either kPa or mm Hg. If the PaO_2 is low, the infant is not getting enough oxygen in the air it is breathing.

3. What do you understand by FiO_2 ?

The FiO_2 is the fraction of oxygen in room air (how much of air the infant is breathing is made up of oxygen). It is measured with an oxygen monitor. The FiO_2 of room air is 0,21 (i.e. 21%). As more and more oxygen is added to the air the infant receives in the head box, the FiO_2 will increase until it reaches a FiO_2 of 1 (i.e. 100%) if the infant receives pure oxygen. The FiO_2 will give you an accurate measurement of how much oxygen the infant is breathing in. This is better than just reading the percentage oxygen on the air-oxygen blender and far better than using the flow meter to control the percentage of oxygen in the inspired air.

4. What is the SaO_2 ?

The SaO_2 is the saturation of oxygen in arterial blood, i.e. what percentage of the haemoglobin in the red cells are saturated (filled) with oxygen.

5. What is the value of knowing all these measurements?

Knowing how much oxygen is being breathed in and how much oxygen is present in the blood is important information as it indicates whether there are problems in the infant's lungs and heart. It also helps to assess how severe the problems are. The more oxygen that is needed to provide normal amounts in the blood, the more severe is the problem.

CASE 2

A 3 day old, term infant has pneumonia in a level 1 hospital and is nursed in an incubator. The infant is cyanosed in room air and needs oxygen therapy.

1. What equipment should be used to administer the oxygen?

The best method to give this infant oxygen would be a perspex head box. Giving oxygen directly into the incubator is unsatisfactory as it uses a lot of oxygen. In addition, high concentrations of oxygen cannot be given and the amount of oxygen in the incubator drops if a porthole is opened.

2. How should you measure the amount of oxygen given?

The concentration of oxygen in the head box must be measured as the fraction (FiO_2) or percentage of oxygen. This is done with an oxygen monitor. The amount of oxygen given should not be measured in litres per minute with a flow meter as this is an extremely inaccurate method of estimating the FiO_2 .

3. How should you control the fraction of oxygen given?

With an oxygen-air blender or a venturi.

4. Why should the oxygen or oxygen/air mixture be humidified?

Because unhumidified gas is very dry and will irritate the linings of the nose, throat and airways.

5. What volume of oxygen/air mixture should be given into the head box?

A flow rate of 5 litres per minute is best. This is measured on the flow meter.

CASE 3

A sick infant with respiratory distress is receiving oxygen via nasal prongs. The FiO_2 is 0,75. Both the tongue and peripheries are pink.

1. What does an FiO_2 of 0,75 mean?

It means that the infant is receiving 75% oxygen.

2. Why should you be unhappy to decide the correct FiO_2 by simply examining the colour of the infant's tongue?

Central cyanosis indicates that the infant does not have enough oxygen in its red cells and, therefore, needs a higher FiO_2 . However the tongue will be pink whether the infant is receiving the correct amount of oxygen or too much oxygen. The FiO_2 of 0,75 may, therefore, be much too high for this infant.

3. How should you measure whether this infant is receiving the correct concentration of oxygen?

The SaO_2 (saturation of oxygen in arterial blood) or the PaO_2 (partial pressure of oxygen in arterial blood) must be measured.

4. How is the SaO_2 measured?

With a saturation monitor which clips onto the infant's hand or foot.

5. How is the PaO_2 measured?

A blood gas analyzer is used to measure the PaO_2 on a sample of blood (usually arterial).

CASE 4

An infant, born after 28 weeks gestation, has hyaline membrane disease and is receiving oxygen by head box. The FiO_2 is 0,55, the SaO_2 is 98% and the PaO_2 is 20 kPa (150 mm Hg).

1. What do you think about the SaO_2 reading?

It is too high as the normal range is 86-92%. This indicates that this infant is receiving too much oxygen.

2. What is the normal range for the PaO_2 ?

The PaO_2 should be between 8 and 10 kPa (60-75 mm Hg). Therefore, the reading in this infant is above the normal range.

3. How would you change the management of this infant?

The FiO_2 must be reduced by adjusting the oxygen/air mixture on the blender or the venturi. The FiO_2 should be reduced by 0,1 (10%) every 15 minutes while watching the SaO_2 . The FiO_2 is correct when the SaO_2 falls within the normal range.

4. What is the danger of too much oxygen in this infant?

Retinopathy of prematurity. The high PaO_2 damages the immature retina and this may cause blindness.

5. What is the greatest danger of giving this infant too little oxygen?

Brain damage.