

Oxygen Therapy: Indications, delivery and doses

Oxygen is the most commonly used life-saving drug in emergency situations to prevent severe hypoxaemia (low arterial oxygen concentration). However, if it is used inappropriately oxygen can have serious or fatal consequences. Oxygen should be regarded as a drug that is prescribed for patients with hypoxaemia (low blood oxygen concentration).

Oxygen should be used to treat hypoxaemia and maintain a patient's saturations between 94-98% or 88-92% in patients who are at risk of type 2 respiratory failure.

When prescribing and administering oxygen there are a number of factors to consider: These are;

1. Does the patient need oxygen?
2. What are the target saturations?
3. How should oxygen be delivered?
4. What is the cause of hypoxaemia?
5. What is the ongoing monitoring?

Hypoxia & hypoxaemia

Hypoxia and **hypoxaemia** are two different terms that can be confusing at times.

In clinical practice, the term 'hypoxic' is commonly used instead of 'hypoxaemic' to refer to a patient with low oxygen saturations as measured on pulse oximetry. Although the terms hypoxia and hypoxaemia are used interchangeably, they mean two different things:

Hypoxia is a failure of tissue oxygenation and hypoxaemia is low arterial oxygen concentration (i.e. low partial pressure of blood oxygen)

Arterial oxygen concentration is measured in kPa. The normal partial pressure of oxygen in arterial blood is 10.6–13.3 kPa. Low arterial oxygenation is known as hypoxaemia and this is the most common cause of hypoxia. However, hypoxia may occur in the absence of hypoxaemia if the peripheral tissue cannot utilise oxygen or oxygen delivery is impaired (e.g. anaemia).

Causes of tissue hypoxia

The five causes of tissue hypoxia include:

- **Hypoxaemic hypoxia:** due to hypoventilation, ventilation/perfusion (V/Q) mismatch, or pulmonary shunts
- **Circulatory hypoxia:** due to inadequate cardiac output

- **Anaemic hypoxia**
- **Histotoxic hypoxia:** inability of the tissue to use oxygen (e.g. cyanide poisoning)
- **Oxygen affinity hypoxia:** decreased oxygen delivery to tissue (i.e. haemoglobin holds onto oxygen)

Indications for oxygen

The sole indication for oxygen is **hypoxaemia**.

Patients with hypoxaemia require oxygen to prevent hypoxia. This is because hypoxia impairs cellular aerobic metabolism. When aerobic metabolism is impaired cells undergo anaerobic respiration, but this is a short-term inefficient system that cannot sustain life for prolonged periods of time.

By-products of anaerobic respiration include substances such as lactic acid that can lead to metabolic acidosis and reduced cellular function.

Oxygen is prescribed for two main groups with hypoxaemia:

Acutely unwell: typically administered in a hospital or healthcare setting.

Chronic hypoxaemia: oxygen may be prescribed for long-term use in patients with chronic lung disease. This is known as long-term oxygen therapy (LTOT). Specific criteria exist for its use.

Hypoxaemia is a common presentation in critically ill patients. Often, patients may be so unwell that oxygen is administered at high flow rates while waiting for a reliable oximetry reading. Once obtained, oxygen can be titrated to the appropriate target saturations.

Oxygen should always be administered to achieve a normal or near-normal oxygen saturation based on the target saturation set for the patient.

Target saturations

Patients with, or at risk of, type 2 respiratory failure should have a lower target saturation at 88-92%.

There are two major target saturations for patients being treated with oxygen:

94-98%: patients not at risk of type 2 respiratory failure

88-92%: patients with, or at risk of, type 2 respiratory failure

The target saturations should be clearly documented or recorded in the patient records.

Type 2 respiratory failure

Type 2 respiratory failure (T2RF) is characterised by hypoxaemia ($\text{PaO}_2 < 6.5 \text{ kPa}$). It is also referred to as hypercapnic respiratory failure. It can be either acute or chronic depending on its

speed of onset and presence of compensatory mechanisms.

Patients at risk of T2RF include:

- Moderate-to-severe chronic obstructive pulmonary disease (COPD): may be undiagnosed
- Cystic fibrosis
- Severe obesity (i.e. obesity hypoventilation syndrome)
- Neuromuscular disease (e.g. Motor neurone disease)
- Severe chest wall deformity (e.g. kyphoscoliosis)
- Previous episode of T2RF

In patients with, or at risk of, T2RF higher levels of oxygen can induce or worsen hypercapnia due to a combination of ventilation/perfusion mismatch and increased physiological deadspace. Therefore, we can get oxygen-induced hypercapnia.

Undiagnosed patients

In a patient without a known diagnosis that increases the risk of T2RF such as COPD, it may be difficult to determine whether they should have a lower target saturation at 88-92%.

Features that can suggest a patient is at risk of T2RF:

- Heavy smoker
- Severe emphysematous changes on imaging
- Compensated respiratory acidosis (i.e. raised PaCO₂ & raised bicarbonate)
- History of obstructive sleep apnoea
- Large neck or very obese
- Rising PaCO₂ with oxygen therapy

Delivery devices

The amount of oxygen that is delivered to a patient to maintain their saturations depends on the device used.

Different devices can be used to deliver oxygen to a patient to maintain oxygen saturations within their target range. These devices vary on the mechanism of delivery, concentration of oxygen given, and whether the delivery of oxygen is fixed or variable.

Nasal cannulae

Oxygen delivered (%): 24-44%

Variable oxygen concentration: affected by respiratory rate and amount delivered via nose.

Flow rate (L/min): 1-6 litres

In general, more than 4 litres is uncomfortable for patients and causes dryness of the nasal passages.

Venturi mask

Oxygen delivered (%): 24-60%

Fixed oxygen concentration: designed to entrain a set amount of oxygen and air giving a fixed concentration

Flow rate (L/min): coloured coded (2-3 Blue / 4-6 White / 8-12 Yellow / 10-15 Red / 12-15 Green)

Simple face mask

Oxygen delivered (%): 30-60%

Variable oxygen concentration: affected by respiratory rate

Flow rate (L/min): 6-10 litres

Non-rebreathe mask

A reservoir bag is connected to the mask with a one-way flap valve.

Oxygen delivered (%): ~60-85%

Variable oxygen delivery: affected by respiratory rate

Flow rate (L/min): 10-15 litres (if lower rates used the reservoir bag can deflate during inspiration)

Humidified oxygen

May be required for flow rates > 4 L/min due to upper airway dryness and discomfort. A humidifier attachment can be added to some devices

Oxygen titration

If a patient is becoming more hypoxaemic, oxygen should be titrated according to target saturations. Ensure ongoing monitoring using appropriate early warning scores (i.e. NEWS). Patients should undergo blood gas analysis within 1 hour of requiring increased oxygen.

Titration of oxygen

1. Stage one - Blue 24% Venturi (2-3 L/min) / Nasal cannulae 1 L/min
2. Stage two - White 28% Venturi (4-6 L/min) / Nasal cannulae 2 L/min
3. Stage three - Yellow 35% Venturi (8-12 L/min) / Nasal cannulae 4 L/min
4. Stage four - Red 40% Venturi (10-15 L/min) / Nasal cannulae 5-6 L/min / Simple face mask 5-6 L/min
5. Stage five - Green 60% Venturi (12-15 L/min) / Simple face mask 7-10 L/min
6. Stage six - Non-rebreathe with reservoir mask 60-85% (15 L/min)

When monitoring patients on oxygen ensure you look for **signs of respiratory deterioration**, particularly if you are required to titrate oxygen upwards. These may include:

- Tachypnoea (esp. >30 bpm)
- Desaturation
- Increasing oxygen requirement
- High NEWS score

Respiratory support

Non-invasive and invasive ventilation is a form of respiratory support to aid ventilation.

Patients with severe hypoxaemia may require respiratory support to aid ventilation. In brief, respiratory support is a method of providing pressure-based ventilation to support a patient's breathing and improve the recruitment of alveoli. There are two major types of respiratory support:

Non-invasive: does not require tracheal intubation

Invasive: requires tracheal intubation and mechanical ventilation

Non-invasive ventilation

Non-invasive ventilation (NIV) is a way of supporting ventilation without having to undergo invasive tracheal intubation. NIV is indicated if high inspired oxygen concentrations (>60%) are not sufficient to maintain adequate oxygenation in patients with respiratory failure.

There are several methods of delivering NIV:

High-flow nasal cannula oxygen (HFNC): often referred to as 'Optiflow'. Provides a high concentration of oxygen (up to 80%) and a high flow rate (up to 70 L/min). Provides a small amount of positive end-expiratory pressure (PEEP - 2-5 cmH₂O). This essentially helps to recruit alveoli and prevent collapse.

Continuous positive airway pressure (CPAP): similar to HFNC, CPAP provides a high concentration of oxygen (up to 80%) and a high flow rate (up to 70 L/min). It provides