

# Oxygen therapy

Oxygen therapy is a treatment that involves the inhalation of oxygen. This therapy may help patients with lung diseases (*e.g.*, cystic fibrosis) and extrapulmonary diseases that prevent sufficient oxygenation of blood (*e.g.*, carbon monoxide poisoning). In such patients, oxygen therapy may improve their **quality of life and lifespan**. Oxygen therapy is usually prescribed by physicians (only in acute cases it can be prescribed by nurses). The protocol contains dosing (*i.e.*, oxygen flow in liters per minute and oxygen concentration) and the method of delivery (type of facial mask or nasal cannula). For successful oxygen therapy, sufficient ventilation is necessary (respiratory muscles must be functional); otherwise, a mechanical ventilator must be used. Oxygen can dry the mucous membranes of the respiratory tract, so it must be administered moistened.

## Types of oxygen therapy

### Short-term oxygen therapy

It is usually performed during hospitalization for **temporary hypoxemia** caused by respiratory diseases. Oxygen is usually delivered using a nasal cannula and rarely using an inhalation mask.

### Long-term home oxygen therapy

Long-term home oxygen therapy is designed for patients with **chronic respiratory insufficiency**, whose health condition is stabilized (*i.e.*, there are no changes in subjective breathing problems and ventilation parameters). Such patients **inhale oxygen for more than 16 hours per day** with pauses that do not exceed 2 hours. Oxygen is typically administered using a nasal cannula and rarely using an inhalation mask. The source of oxygen can be an oxygen concentrator (a device that purifies oxygen from ambient air), a liquid oxygen canister, or a flask of pressurized oxygen.

**The aim of long-term oxygen therapy is to increase the quality of life of patients, decrease the risk of their hospitalization, and decrease disease exacerbation and the risk of death.**

### Criteria for indication of oxygen therapy

The criteria are:<sup>[1]</sup>

1. **PaO<sub>2</sub> (arterial PO<sub>2</sub>) at rest is below 7,3 kPa.**
2. PaO<sub>2</sub> is 7,3–8,0 kPa and the following are observed simultaneously in the patient:
  1. Signs of pulmonary hypertension or right ventricular hypertrophy
  2. Secondary polycythemia (as a consequence of chronic hypoxemia)
3. Desaturation (*i.e.*, low PaO<sub>2</sub>) during sleep (diagnosed with noninvasive overnight monitoring of SpO<sub>2</sub>). SpO<sub>2</sub> below 90% for 30% of sleep duration is indicated.
4. Desaturation during physical exercise (when 50 W of activity for at least 5 minutes leads to a PaO<sub>2</sub> below 8 kPa in resting normoxemic patients).
5. Bronchopulmonary dysplasia in premature infants without the risk of retinopathy that require oxygen therapy (when SpO<sub>2</sub> is below 92%).



Reduction valve with flow-meter

The aim of oxygen therapy is to reach the following partial pressure and saturation levels:

- PaO<sub>2</sub> ≥ 8,0 kPa.
- SpO<sub>2</sub> in arterial blood ≥ 90%

**Contraindications of oxygen therapy** include hypercapnia, being a smoker, and noncompliant patients (especially smokers as there can be a risk of ignition when oxygen is exposed to flames).

### Risks of oxygen therapy:

1. Generation of oxygen radicals (reactive oxygen species, ROS),
2. Decreased ventilation: especially in patients with high P<sub>CO2</sub>, where the major breathing stimulus is hypoxia; for example, in chronic obstructive pulmonary disease (COPD) – "blue bloaters"
3. Lung exudation, congestion, and edema
4. Atelectasis: the collapse of alveoli with trapped air following air resorption.
5. Seizures: breathing of O<sub>2</sub> under high pressure inhibits CNS enzymes.

## Humidification

To avoid the drying of mucous membranes, a gas humidifier should be employed.

- Gas humidifiers – employ water vapor
- Nebulizers – saturate the air with aerosol
- Micronebulizers – can saturate the passing gas with drugs for simultaneous therapeutic purposes (*e.g.*, with Mucosolvan or Bromhexine)

## Standard practice

- Oxygen promotes combustion, can be explosive in specific concentrations, so it must be handled carefully.
- Open flames and other risks of ignition must be avoided.
- Oxygen flow rate and concentrations must be regulated with flow regulator valves.
- When handling oxygen, hands must be grease-free and the valves should not be lubricated.
- Oxygen must be moisturized (humified) and heated to body temperature
- During oxygen administration, the patient's respiratory rate, oxygen saturation, heart rate, and blood pressure must be monitored.
- The involvement of accessory respiratory muscles should be observed.

## Oxygen supply

- Central oxygen supply – oxygen is stored in one designated place in the hospital and it is delivered via pipelines into the site of need. It is usually delivered by pipes into every room near every bed to a panel with an oxygen connector.
- Steel cylinder with pressurized oxygen – oxygen is stored under pressure up to 15,2 MPa (150 atm). It must be handled with extreme caution.

The **reduction valve** decreases the pressure of oxygen (it is attached to the central oxygen supply panel or the steel cylinder)

Additional devices:

- Oxygen flow meter
- High-pressure manometer (enables the measurement of total oxygen pressure in the cylinder or central supply)
- Low-pressure manometer (enables the measurement of oxygen pressure supplied to the patient)
- Main shutdown valve
- Humidifier

### Cylinder markings:

- Blue stripe (outdated, but can still be seen rarely)
- Blue stripe with a white stripe above it and the (usually black) letter N (stands for "new")

Regardless of color, the content of the cylinder must be clearly stated on its label (usually near its top)

Note: empty cylinders must be stored separately from full cylinders and cylinders cannot be exposed to heat, direct sunlight, or open flames. Cylinders cannot be stored in narrow corridors. During transportation, cylinders must be fastened to prevent falling.

### Estimation of residual content of the cylinder

If a cylinder has a volume of *e.g.* 10 liters and the original pressure is 150 atm, the amount of gaseous oxygen in the cylinder can be estimated by multiplying the volume (10 liters) times the pressure (150 atm):  $10 \times 150 = 1500$  L O<sub>2</sub>. This is the equivalent of approximately 1500 L of gas at ambient temperature and pressure.

If the oxygen is partially consumed and the pressure in the cylinder decreases to *e.g.* 50 atm, the amount of remaining oxygen can be estimated as well:  $10 \times 50 = 500$  L O<sub>2</sub>. This is the equivalent of approximately 500 L of gas at ambient temperature and pressure and would be sufficient for approximately 4 hours if the flow is 2 L/min:  $500/2 = 250$  min, which is equivalent to 4 hours and 10 minutes.

## Administration

- Nasal catheter – it is inserted into the nose parallel to the *meatus nasi inferior* to the depth of *uvula*. The insertion is facilitated by the patient's swallowing reflex. The flow rate is set to 4 to 6 or 7 L per min and the oxygen concentration is set to 50 to 60%. It is important to secure the nasal catheter so that it does not slip (either out or into the esophagus). The catheter should be replaced every 12 hours; otherwise, there is a risk of infection.
  - Poulsen catheter – a modified version of the nasal catheter. Its ending contains a polyurethane seal around the tube (ca. 2-3 cm long), which prevents oxygen leakage; thus, it increases the concentration of inhaled oxygen. Also, it does not dry out the respiratory mucosa.
- Nasal oxygen cannula – used in long-term oxygen therapy, it consists of a flexible tube with two stiff short endings in the middle that are inserted into the nostrils. The oxygen flow rate is approximately 5-6 liters per minute. Its major benefit is that it does not limit the patient significantly; however, its efficacy is fairly low: the

oxygen gets mixed with air and the final concentration of oxygen is approximately 30%.

- Oxygen mask – made from a transparent material (plastic) with a soft metal frame. It is held in place using a rubber band around the head of the patient. The flow rate is usually 7-12 liters per minute. The major benefit of this device is its high efficacy and good tolerance to high flow rates. However, masks should be avoided in patients with a tendency to vomit. Furthermore, some patients do not tolerate the masks well (*e.g.*, anxious patients). An oxygen mask can also include a balloon, which functions as a reservoir (it inflates when the patient is not inhaling and deflates when the patient inhales). The balloon decreases the loss of gas and, importantly, increases the oxygen concentration in the inhaled gas up to virtually 100% (in reality it is still 60 to 80%).
  - Venturi mask – an O<sub>2</sub> mask with a specific connector, that enables the regulation of oxygen concentration. It is used for patients with time-variable oxygen requirements.
- Incubator – oxygen therapy for premature infants. Oxygen concentration, temperature, light, and humidity are closely controlled and monitored.
- Oxygen tent: it is used in patients that do not tolerate gas masks (*e.g.*, with facial wounds, anxious patients).
  - for children – usually manufactured from plexiglass
  - for adults – a room for two to three patients or a tent with a metal framework and gas-impervious foils
- Nebulizer – an auxiliary device that enables the formation of aerosol with drug droplets. It is used for inhalation drug therapy.
- Hyperbaric chamber – a high-pressure chamber that enables the pressurization of air/air-oxygen mixture around the patient and thus can increase the oxygen solubility in blood. It is used in the therapy of carbon monoxide poisoning (see below)

Note: The maximum gas flow is always declared by the manufacturer.

## Fraction of inspired oxygen (F<sub>I</sub>O<sub>2</sub>)

The fraction of inspired oxygen is the relative volume of oxygen in the inhaled gas. During oxygen therapy, the aim is to increase the F<sub>I</sub>O<sub>2</sub> to 30% or more (ambient F<sub>I</sub>O<sub>2</sub> is 21%). The higher F<sub>I</sub>O<sub>2</sub> is, the more efficient the oxygen therapy is. The efficacy varies with different methods of delivery and oxygen flows.

Method of delivery ↕	Oxygen flow L/min. ↕	F <sub>I</sub> O <sub>2</sub> ↕
Nasal catheter	5	0,4
Oxygen mask	5-6	0,4
Oxygen mask	6-7	0,5
Oxygen mask	7-8	0,6

## Hyperbaric chamber

A hyperbaric chamber is a type of oxygen therapy that exposes the patient to almost 100% oxygen at **increased gas pressure**. The patient is enclosed in a slowly pressurized steel chamber (usually approximately 20 minutes or more). The pressure is maintained (up to 200 kPa for 90 to 120 minutes) and is then slowly decreased to reach the atmospheric pressure to terminate the therapy.

### Purpose

- Treatment of tissue hypoxia → improved wound healing
- Increased perfusion → decreased edema, increased venous return
- Alteration of metabolic processes in peripheral tissues and skin
- Support of angiogenesis of capillaries
- Improved vascular wall function
- Increased granulation and epithelization

### Types of hyperbaric chambers:

#### 1) By number of seats

- Single-seat (single patient) chambers are pressurized directly with the oxygen the patient is breathing.
- Multi-seat chambers are pressurized with air and the patient breathes oxygen using a special device: either a valve or an oxygen helmet (through which oxygen flows continuously). Multi-seat chambers are most often cylindrical in shape for 2 to 16 seated patients. The state-of-the-art chambers are cube-shaped (like a room) and have equipment identical to the intensive care unit's bedside treatment for critically ill patients.

#### 2) By inhaled gas

- Filled with air.
- Filled with oxygen – patients breathe oxygen directly from the chamber's environment. This is associated with a high risk of fire.

During the treatment, a pressure 2.5 to 3 times higher than atmospheric pressure is commonly used. This pressure corresponds to the pressure experienced at a depth of 15 to 20 meters below water. One session lasts 90 minutes. The treatment is repeated once a day, 5 times a week, for 3 weeks.

It utilizes the blood's ability to deliver more oxygen to organs under these higher pressures. Under high pressure, oxygen dissolves in the plasma while minimizing the volume of air bubbles.

**Indication:** according to urgency assessment

I. Grade - affects the prognosis of survival, it is a vital indication.

II. Grade - is an important part of the treatment, prevention of serious complications.

III. Grade - is part of a comprehensive treatment, significantly improving clinical outcomes.

**Contraindications:**

- **Absolute** - untreated pneumothorax, treatment with cardiotoxic cytostatics, disulfiram therapy, cisplatin therapy, doxorubicin therapy, premature infants (risk of retinopathy)
- **Relative** - acute viral infections HCD with elevated body temperature, malignant carcinoma, claustrophobia, pregnancy, acute asthma...

**Complications:**

- Barotrauma
- Oxygen toxicity
- Nitrogen narcosis
- Myopia
- Bradycardia

**The process:**

1. Compression: It involves **slowly** increasing the pressure around the patient, which could be uncomfortable for some patients. The chamber heats up (due to gas contraction).
2. Pressure maintenance: Once a pressure of 200 kPa (2 atmospheres) is achieved, it is maintained for 90 to 120 minutes. This phase is well-tolerated.
3. Decompression: Pressure is decreased **slowly**. The temperature of the chamber decreases (due to gas expansion - fog may appear). This process is usually well-tolerated (better than the compression phase).

## Types of diseases requiring oxygen therapy

- Hypoxemia, hypoxia, anoxia, anoxemia,
- Lung disease
  - COPD - usually in stadiums III and IV
  - Pneumoconiosis - very advanced stages
  - Beginning with pulmonary edema
  - Bronchospasm
  - Pulmonary fibrosis
  - Severe asthma
- Pulmonary vascular disease
  - Pulmonary arterial hypertension
- Neurological diseases,
  - Myopathy
- Diseases of the chest wall
  - Severe kyphoscoliosis of the thoracic spine
- Respiratory insufficiency in severe obesity
- Postoperative period
- Shock
- Severe anemia
- Circulatory disorders
- AIM
- Carbon monoxide poisoning
- Perinatal period

**Flow of oxygen delivered:**

- Adult - 4-10 l / min,
- Children - 1-4 l / min.

## References

### Related articles

- Oxygen toxicity
- Hyperbaric oxygen therapy
- Oxygen
- Reactive oxygen species
- Oxygen parameters
- Hypoxia
- Hypoxemia

## Literature

- Česká pneumologická a ftizeologická společnost ČLS JEP. Terapie kyslíkem v domácím prostředí - DDOT. 2010. Dostupné také z URL <<http://www.pneumologie.cz/odborne/doc/DDOT-novela%20standardu-prosinec%20%202009-pripom%201.doc>>.
- ČEŠKA, Richard, et al. *Interna*. 1. vydání. Praha : Triton, 2010. 855 s. s. 460-465. ISBN 978-80-7387-423-0.
- Česká pneumologická a ftizeologická společnost ČLS JEP. Terapie kyslíkem v domácím prostředí - DDOT. 2010. Dostupné také z URL <http://www.pneumologie.cz/odborne/doc/DDOT-novela%20standardu-prosinec%20%202009-pripom%201.doc>
- ERTLOVÁ, F., MUCHA, J.; Přednemocniční neodkladná péče; Brno NCONZO, 2003; 2 přep. vyd.; ISBN 80-7013-379-1

## External links

- Osacká Petronela: Oxygenoterapia, inhalácie, termoterapia. Multimediálna podpora výučby klinických a zdravotníckych disciplín :: Portál Jesseniovej lekárskej fakulty Univerzity Komenského [online] 4.2.2011, posledná aktualizácia 2.12.2011 [cit. 2011-12-23] Dostupný z WWW: <<https://portal.jfmed.uniba.sk/clanky.php?aid=139>>. ISSN 1337-7396
1. ČR. Česká pneumologická a ftizeologická společnost ČLS JEP. Terapie kyslíkem v domácím prostředí - DDOT. 2010. Dostupné také z URL <<http://www.pneumologie.cz/odborne/doc/DDOT-novela%20standardu-prosinec%20%202009-pripom%201.doc>>.