OXYGEN THERAPY – GUIDELINESS, BENEFITS AND RISKS FOR ADULT PATIENTS

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Abstract
The aim of oxygen therapy is to enrich the oxygen inhaled air in such an amount to maintain oxygen saturation in the blood above 90 %. Oxygen has specific biochemical and physiological functions, wide dosage range, but it also has undesirable effects. Administration of oxygen without hypoxemia or hypoxia is potentially harmful. The administration of high doses of oxygen over 50 % longer than 24 hours is at risk. Clear airways, preserved function of the pulmonary alleles and respiratory muscles and functional blood circulation is a prerequisite for effective oxygen therapy. The aim of the paper is to provide the review of the latest recommendations in oxygen therapy with emphasis on its benefits and the risks arising from evidence-based practice.

Key words: Oxygen Therapy. Applications of Oxygen. Risks of Oxygen Therapy. Hyperbaric Oxygen Therapy

1 Introduction

Oxygen therapy is usually defined as the administration of oxygen at concentrations greater than those found in ambient air. It is usually undertaken to treat or prevent hypoxmia, thereby preventing tissue hypoxia which may result in tissue injury or even cell death. Clinicians must bear in mind that supplemental oxygen is given to improve oxygenation but it does not treat the underlying causes of hypoxmia which must be diagnosed and treated as a matter of urgency [1]. The healthy adult human can, under physiological conditions, breath in approximately 15 times per minute, while inhales the mixture of gases composed of oxygen (20.99 obj %), nitrogen (78.03 obj %), carbon dioxide (0.03 obj %) and others or so-called of rare gases (0.95 obj %). From this mixture, there is unconditionally needed for life only oxygen that is bound to hemoglobin, and thus 97 % is transported from the lungs into tissues. The remaining 3 % of oxygen is dissolved in blood plasma [2, 3]. Saturation of hemoglobin by oxygen is considered to be a vital function (blood pressure, pulse, breath, body temperature) [1].

2 Hypoxemia

An indication for oxygen therapy is hypoxemia that occurs when oxygen saturation is below 95 %. The most important indication for oxygen therapy is the degree of hypoxemia, whether CO_2-free or with retention CO_2. Depending on the degree of hypoxmia determined by the value of PaO_2, the indications are absolute (with PaO_2 below 40 mm Hg), urgent (with PaO_2 below 30 mm Hg) and relative (with PaO_2 above 50 mm Hg). Oxygen should be prescribed with the aim to achieve 94 to 98 % saturation for most critically ill or 88 to 92 % of those at risk of hypercapnia respiratory failure. Hypoxemia has four main causes: hypoventilation, oxygen diffusion disturbances through the alveolocapillary membrane, arterio-venous shortness and ventilation-perfusion imbalance. Patarinski in 1976 [4] describes that preventive treatment of O_2 (without hypoxemia) is inappropriate because of potential harmful side effects of oxygen. Driscoll et al. believes that no apparent oxygen terapy effect was demonstrated in respirable patients without hypoxemia. Oxygen administration is usually indicated for heart failure, accidents associated with insufficient oxygenation of the blood, respiratory diseases (CHOCHP, asthma bronchiale, pneumonia), and anemia. The basis of effective oxygen treatment is the clear airways, preserved function of the lung alveolas and respiratory muscles, transport of oxygen (Hb) and functional blood supply [5]. In particular, it is necessary to assess the need for oxygen in patients in palliative care, taking into account the presence of anxiety and pain as the factorst that contribute to shortness of breath and subsequent hypoxemia. A specific approach requires pregnant women. According to the latest recommendations, women with hypoxemia who are > 20 weeks of pregnancy should be positioned on their left side to improve their cardiac output. During childbirth, oxygen is often administered, but it has been proven to be harmful to the fetus. Therefore, it is currently not recommended to administer oxygen during labour in situations where the mother is not hypoxic. When administering oxygen, it is important to always remember that oxygen therapy itself does not solve the cause of hypoxemia [1].

3 Hyperoxemia

The administration of high doses of oxygen with a concentration greater than 50 % longer than 24 hours may cause hyperoxemia. Hyperoxemia is generally considered to be deleterious, it causes increased mortality in patients with stroke, brain injury and in resuscitation after blood flow stopped [6]. The first signs of hyperoxia include chest pain, coughing, dizziness, cramping (high oxygen concentration causes reflex reduction, hemopoiesis, decreased heart rate, decreased blood flow to the kidneys and brain). And finally, retinopathy (retinal detachment) and blindness develop.

Hyperoxmia has been shown to be beneficial in the following clinical situations:

- Carbon monoxide and cyanide poisoning,
- Spontaneous pneumothorax,
- Postoperative complications,
- Cluster headache.

Aside from the potentially detrimental physiological effects of hyperoxmia, the toxic effects mediated by reactive oxygen species (ROS) have potential risk (tab 1). Excess ROS are generated in the presence of high tissue PO_2 in the form of hydrogen peroxide and superoxide, causing oxidative stress and free radical damage. At physiological levels ROS act as signalling molecules, but at higher levels these are cytotoxic, notably being released by primed neutrophils as a host defence mechanism. It is thought that ROS are responsible for the development of bronchopulmonary dysplasia in ventilated hyperoxygenated premature infants and reperfusion injury postmyocardial infarction. It has been known since the 19^{th} century that prolonged exposure to high concentrations of oxygen in animal models leads to diffuse alveolar damage, hmorrhage, alveolar collapse, infiltration of inflammatory cells, necrosis, apoptosis and injury to the endothelium and epithelium in the lungs which causes death in the rat model after 4 days of exposure to 73 % oxygen at one atmosphere. Griffith et al. demonstrated in 1986 that normal human lungs are injured by breathing 30–50 % oxygen for 45 hours with leakage of albumin into bronchoalveolar lavage fluid and other markers of lung injury [1].

The administration of oxygen not to hypoxemic patients should be re-evaluated because there is no evidence of its beneficial effect. If Hb is fully saturated, the addition of oxygen only slightly increases the transport capacity of oxygen for oxygen. On the contrary, the supply with oxygen paradoxically decreases, which can be caused by vasoconstriction [6].

Tab 1 *Summary of risks of hyperoxmia and supplemental oxygen therapy*

Physiological risks	**Clinical risks**
Worsened V/Q mismatch.	Worsening of hypercapnic respiratory failure.
Absorption atelectasis	Delay in recognition of clinical deterioration.
Coronary and cerebral vasoconstriction.	Potentially worse outcomes in mild-to-moderate stroke.
Reduced cardiac output.	Specific risk in patients with previous bleomycin lung damage or with paraquat poisoning or acid aspiration.
Damage from oxygen free radicals.	Unknown risk–benefit balance in acute coronary artery disease with normal oxygen saturation.
Increased systemic vascular resistance.	Association with increased risk of death in survivors of cardiac arrest and among patients on ICUs.
-	Uncontrolled supplemental oxygen therapy can be harmful to patients who are at risk of hypercapnic respiratory failure, especially if the PaO2 is raised above 10 kPa.
-	High-concentration oxygen therapy to produce hyperoxmia (above normal oxygen saturation) and has been associated with increased risk of death in some patient groups (eg, patients with mild and moderate strokes, survivors of cardiac arrests and ICU patients).

4 Oxygen Therapy - Guideliness

Oxygen delivery systems can be considered as two components:

- The method of storage and provision of oxygen (eg, cylinders);
- The method of delivery to the patient.

The options available for both will depend on the environment in which it is being used and the needs of the patient.

Cylinders contain compressed gas held under a very high pressure. They come in an array of sizes and hence capacity, ranging from small portable cylinders for individual patient use to large cylinders suitable for hospital use. Oxygen supports combustion and there is a risk of fire if oxygen is used close to combustible materials and a source of ignition.

The administration of oxygen is strictly related to the observance of certain safety measures [1, 7-12]:

- Oxygen bottle should be labeled with white color at the top and with black inscription O_2.
- The oxygen bottle must be secured against fall by attaching to the pedestal, in a dark, dry, clean room without electrical appliances and the possibility of contact with fire.
- All cylinders must be secured appropriately so they cannot move in transit (includes portable cylinders).
- No smoking in the vicinity of cylinders.
- Cylinders must be checked regularly for obvious signs of leakage.
- Cylinders must be kept out of direct sunlight.
- It is essential to check the fullness of the bottle prior to administration of oxygen.
- Prior to each administration of oxygen, it is essential to verify the identity of the patient by addressing him/her according to identifying the bracelet. It is essential to observe the oxygen concentration, flow rate and route of administration. For the oxygen bottle, a pressure reducing safety valve and an oxygen humidifier must be fitted before administration. A flow meter and an oxygen humidifier are connected to the central oxygen distribution.
- In order to achieve the therapeutic effect, the position of the patient is preferred in the half-sitting position or in the seated position and the provision of airway passage by aspiration of the mucus.
- Oxygen delivery must be documented.

Oxygen applicators are selected according to the length of oxygen delivery, safe administration criteria, patient age, personal preferences, amount of oxygen administered, and overall health condition of a patient. In general, oxygen therapy devices must be safe and should limit the patient as little as possible [6].

5 Face mask

Face oxygen masks can be simple or with a reservoir (10 % oxygen utilisation, flow rate 5 to15 l per min). This type of mask delivers oxygen concentrations between 40 % and 60 %. Patients using a simple face mask may have an inspiratory flow rate greater than the gas flow rate from the mask, so the simple face mask should not be used at flow rates below 5 l per min [1]. The patient's head is fastened using an elastic band. The mask covers the mouth and the nose, while it should fit the best to the face. On the sides there must be holes for exhaled carbon dioxide. This type of device is not suitable for long-term use, for children, for unconscious patients who are at risk of vomiting and subsequent aspiration of gastric contents [10]. This mask is suitable for patients with respiratory failure without hypercapnia (type 1 respiratory failure), but is not suitable for patients with hypercapnic (type 2) respiratory failure. The specific type of oxygen mask is Venturi mask.Venturi masks are available in the following concentrations: 24 %, 28 %, 31 %, 35 %, 40 % and 60 %. Venturi masks are particularly suited to those at risk of carbon dioxide retention. A further benefit of Venturi masks is that the flow rate of gas from the mask will usually exceed the inspiratory flow rate of the patient [13].

6 Nasal cannul

Oxygen glasses, oxygen catheter – nasal sinus Nelaton catheter, exceptionally Poulsen catheter with a plug (allowing a flow of 4 to 6 l per min.). The nasal Nelaton Catheter is a plastic spool with several openings. It enters through the nose to the soft climate [11]. Nasal cannul can be used to deliver low-concentration and medium-concentration oxygen concentrations [1]. When the mouth is opened, the catheter must be seen. It is suitable for unconscious patients, as there is no risk of aspiration. It can be introduced in the long run. The disadvantage of applicator is excessive mucous membrane dryness [10]. Some patients may experience discomfort and nasal dryness at flows above 4 l per min. For this reason it is currently less used. The Poulsen catheter is a plastic spool that passes through the center of the foam stopper. It is inserted approximately 2 cm into one of the nostrils and then sealed with foam. An advantage is the constant oxygen concentration.The upper range of oxygen delivery from nasal cannul is a little lower than the output of a simple face mask, but the lower range goes a lot lower than a simple face mask which should not be used below a flow rate of 5 l per min (about 40% oxygen) [14]. Advantages of nasal cannul compared with simple face masks for medium-concentration oxygen therapy [1]:

- Comfort (but a minority of patients dislike the flow of oxygen into the nose, especially above 4 l per min).
- Adjustable flow gives wide oxygen concentration range (flow rate of 1–6 l per min gives FiO_2 from ~ 24 % to ~ 50%), suitable for variable oxygen therapy and concentration titration.
- Patient preference.
- No claustrophobic sensation.
- Not taken off to eat or speak and less likely to fall off.
- Less affected by movement of face.
- Less inspiratory resistance than simple face masks.
- No risk of rebreathing of carbon dioxide.
- Cheaper.

Disadvantages of nasal cannul:

- May cause nasal irritation or soreness.
- May not work if nose is severely congested or blocked.
- Actual concentration of oxygen (FiO2) cannot be predicted.

7 High-flow humidified oxygen via nasal cannul (HFNC)

There is increasing use of HFNC as an alternative delivery device for adults requiring medium-concentration and highconcentration oxygen therapy. High Flow Nasal Ventilation (HFloNV) has also been started to be applied in adults through sealed binasal cannula to deliver 37°C heated and 100% humidified gas. Gas flow (40-60 l/min) through cannula generates overpressure in nasopharynx, which subsequently produces dynamic positive endexpiratory pressure (PEEP). That is better tolerated than classic CPAP applied nasally or by facemask. The high potential benefit of this ventilatory support is the ability of HFloNV to continually remove CO2 from nasopharynx and upper airways. HFloNV ventilatory support has been introduced in patients with hypoxic respiratory failure (ARDS 1.level, lung fibrosis, COPD, pneumonia, lung edema, cardiac surgery with respiratory insuficiency, postextubation respiratory insuficiency, morbidly obese patients, do-not-intubate terminal patients). However some papers have already shown that liberal application of HFloNV may lead to its failure and subsequent prolonged intubation and controlled ventilation and possibly to increased 30-day mortality in some patients [15]. Use of HFNC oxygen compared with conventional oxygen therapy reduced the risk of reintubation within 72 hours. A prospective sequential comparison trial by Roca et al. [16] examined 20 patients with acute hypoxmic respiratory failure and compared HFNC with conventional oxygen therapy. HFNC was better tolerated and more comfortable than face mask. HFNC was associated with better oxygenation and lower respiratory rate. Cuquemelle et al. [17] also reported greater patient comfort using this system. In further support a study by Parke et al. [18] 60 patients with mild-to-moderate hypoxemic respiratory failure were randomised to receive HFNC or high-flow face mask and they analysed the success of allocated therapy, NIV rate and oxygenation. Frat et al. [19] randomised 310 patients with acute hypoxmic respiratory failure (without hypercapnia) to treatment with HFNC, reservoir mask or NIV and they found that HFNC increased the number of ventilator-free days and reduced 90-day mortality but did not significantly reduce the intubation rate which was the primary end point of the study.

8 Hyperbaroxy

Hyperbaric chamber is a specially adapted environment in which the patient inhales 100% oxygen at a pressure of more than 1 atmosphere. During hyperbaric therapy, oxygen dissolves in all the body fluids (for example blood plasma, lymph, and cerebrospinal fluid) and penetrates into ischemic (pallid) areas deeper than at normobaric pressure. Increased O_2 concentrations in the body, together with higher pressures, work in a comprehensive way, which in combination with a higher pressure gives hyperbaric oxygen therapy (HBOT) unique therapeutic options. HBOT stimulates robic metabolism, reduces lactate production, eliminates local acidosis, allows for greater diffusion of oxygen into tissues, has bactericidal effects on anrobic bacteria, promotes angiogenesis, regenerates nerve cells, reduces edema, and many others. Based on the results of numerous studies, this is the indication for HBOT treatment:

- Decompression sickness,
- Gas embolism,
- Exceptional Blood Loss (Anemia),
- Carbon Monoxide Poisoning (CO),
- Clostridal Myositis and Myonecrosis(Gas Gangrene),
- Anrobic infections,
- Diabetic legs and non-healing wounds,
- Necrotizing Soft Tissue Infections, Selected Problem Wounds,
- Buerger’s disease,
- Atherosclerosis,
- Crohn’s disease, ulcerative colitis,
- Atopic dermatitis,
- Some hearing and balance disorders,
- Osteomyelitis,
- Stroke,
- Multiple sclerosis,
- Burns, frostbite,
- Conditions with insufficient oxygenation,
- Inflammatory and immune mediated diseases.

The curative effect is not immediate, but the patient begins to manifest after a certain time. The number of exposures in the hyperbaric chamber from 10 to 30 and the duration of one exposure is generally in the range of 60 to 90 minutes. The hyperbaric chamber is a steel or acrylic pressure vessel in which technical standards and a hyperbaric environment must be provided. There are several types of chambers that are broken down by purpose. They are, for example diving chambers, chambers used for experimental purposes and treatment chambers. By size, we recognize small chambers approximately 1 m^3, medium with an internal volume of 4 to 8 m^3 and large chambers 10 and more m^3. Small chambers are usually filled with oxygen, patients in this type of chamber inhale oxygen directly from the environment. Large chambers are generally filled with air, and oxygen is administered to the patient with a face mask or an oxygen helmet [20].

9 Conclusion

The appropriate device should be used to provide the prescribed oxygen and the effects should be monitored using pulse oximetry, monitoring of respiratory rate and close observation of the patient. Arterial or capillary blood gas analysis should be repeated if clinical progress is not satisfactory and in all cases of hypercapnia and acidosis. Safe prescribing and safe administration of oxygen are closely linked. In emergencies, oxygen therapy should be started immediately and documented as soon as possibleThe healthcare professional who administers the oxygen therapy (usually a nurse or physiotherapist) should be fully trained and should follow local or national protocols.

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