OXYGEN THERAPY

WHY DOES THE BODY NEED OXYGEN?

Every function in the body requires oxygen. Oxygen is needed to complete the metabolism of glucose to produce ATP which provides energy.

If inadequate amounts of oxygen reach the cells, organ function will be compromised:

- Alterations in brain, cardiac, and kidney function
- Reduced ability of the diaphragm muscle to work
- Alteration in the ability to digest/absorb food
- Fatigue or generalized muscle weakness

If oxygen deficiency is prolonged, permanent organ injury or death may result.

Pulmonary System
The pulmonary system is responsible for external and internal respiration.

3 Stages of Respiration:

1. External Respiration: the delivery of atmospheric oxygen (O₂) to alveoli and the exhalation of carbon dioxide (CO₂) produced by the tissues.

2. Intermediate Respiration: the transport of O₂ and CO₂ via hemoglobin (Hb) and a dissolved component between the lung and tissue cells of the body.

3. Internal or Cellular Respiration: red blood cells release O₂ and absorb CO₂ produced by cellular metabolism at the tissues.

Ventilation is the movement of air whereby respiration is the exchange of oxygen and carbon dioxide between the alveoli and the blood.
MECHANISMS OF A BREATH

During Inspiration
During a normal inspiration, the diaphragm descends, pulling the pleura apart, producing a negative pressure in the alveoli. This causes a pressure gradient from the upper airway leading to gas flow.

At End Inspiration
The air flows down the pressure gradient until the alveolar pressure equals zero and the gradient for flow stops. The lungs and chest are fully expanded.

During Expiration
The inspiratory muscles relax, causing lungs to recoil, and the diaphragm ascends. This causes an abrupt ↑ in pleural and alveolar pressure creating a pressure gradient from the alveoli to the mouth causing air to flow out of the lungs.

At the End of Expiration
The pleural space and the alveoli return to the pressures they had at the start of inspiration. I.e. Pleural pressure is negative and alveolar pressure is zero, i.e. atmospheric pressure.

No movement of air occurs.
HOW IS OXYGEN DELIVERED TO THE CELLS OF THE BODY?

Getting enough oxygen to the cells of the body requires four different functions:

1. The lungs must be able to adequately ventilate in order to take in enough oxygen
2. There must be enough Hb to carry oxygen from the lungs to the cells
3. The heart must have adequate cardiac output
4. The cells of the body must be able to extract oxygen from the blood stream

Oxygen is carried in the blood in 2 ways:

1. Dissolved (2%)
2. Bound to hemoglobin (Hb) – the primary carrier of oxygen (98%)

The amount of oxygen in the blood that will be available to the tissues is determined by this oxygen carrying capacity and the cardiac output.
INDICATIONS FOR OXYGEN THERAPY

Hypoxemia  
PaO₂ < 60 mmHg  
SaO₂ < 90%

Oxygenation Failure  
PaO₂ < 60 mmHg or SaO₂ < 90% with FiO₂ > 0.50

WHO REQUIRES OXYGEN THERAPY?

3 physiological causes of hypoxemia:
These factors influence the transport of oxygen from the alveoli to the pulmonary capillaries:

1. **Diffusion defects**: Thickness of alveolar wall, area available for gas exchange and the partial pressure difference between the alveoli and the capillaries. E.g. Lung fibrosis, pulmonary edema. Giving supplemental oxygen ↑ partial pressure gradient for oxygen

2. **Ventilation perfusion mismatch**:
   a. Deadspace: Alveoli are ventilated but not perfused. E.g. PE, hypoperfusion
   b. Intrapulmonary shunt: Alveoli are perfused but not ventilated.  
   E.g. consolidation (alveoli filled with exudate), perioperative atelectasis, or “acute lung injury” where there is alveolar edema and capillary microthrombosis

3. **Cardiac output**: Determined by preload, afterload and contractility. If CO is decreased, the amount of oxygen available at the tissues may be decreased.
OXYGEN THERAPY

PROBLEMS PREVENTING THE TISSUES FROM RECEIVING ADEQUATE OXYGEN

Respiratory:
- COPD, Emphysema, Asthma
- Pulmonary edema, Pneumonia, Pneumothorax
- Malignancies of the lung
- Flair chest/rib fractures
- Excessive sedation

Cardiovascular: poor cardiac function reduces the delivery of oxygen from the lungs to the cells.
- Congestive heart failure
- Inadequate fluid volume/dehydration
- Myocardial infarction
- Arrhythmias
- Pulmonary embolus

Haemoglobin Problems: ↓ Hb reduces the ability to carry oxygen from the lungs to the cells. E.g. Haemorrhage, anemia,

Cellular Problems: Less common. The inability of the cells to use oxygen
E.g. Cyanide poisoning, carbon monoxide poisoning, severe edema, septic shock

SIGNS OF RESPIRATORY DISTRESS

Regardless of the cause of hypoxemia, the body will try to compensate first with the cardiopulmonary system: by increasing minute ventilation and cardiac output.

- Tachypnea
- Dyspnea, shortness of breath
- Wheezes or crackles
- Use of accessory muscles, increased abdominal movement
- Tachycardia
- Hypotension or hypertension

When this fails to increase oxygen delivery to the cells, the signs and symptoms seen are due to lack of oxygen to the cells.

- **Altered perfusion to the brain**: Confusion, combativeness, restlessness, ↓ level of consciousness
- **Altered tissue perfusion**: Hypotension, cyanosis, cool or pale skin, ↓ capillary refill, diaphoresis
SUPPLEMENTAL OXYGEN

Room Air = 21% Oxygen or FiO₂

Supplemental oxygen increases the partial pressure gradient for oxygen, thereby reducing the need for the cardiopulmonary system to compensate:

- ↓ WOB
- ↓ HYPERVENTILATION
- ↓ TACHYCARDIA
- ↓ WORK OF HEART

When Is Oxygen Therapy Alone Not Enough?

If the surface area available for gas exchange is reduced significantly due to respiratory problems such as alveolar edema, consolidation, or atelectasis, PEEP may be required by using BiPAP or mechanical ventilation.

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<tr>
<th>GOAL</th>
<th>PaO₂ &gt; 60 mmHg or SaO₂ &gt; 90%</th>
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OXYGEN THERAPY

OXYGEN DELIVERY DEVICES

2 Categories: Low-flow devices
               High-flow devices

Whether a device is classified as a low-flow or high-flow system depends on the total flow of gas from the oxygen device and whether it meets the patient’s peak inspiratory flow (how deep they take a breath)

Peak inspiratory flow rate: Normal = 60 lpm

Take a deep breath in: you have probably just inspired 1 liter of air in about 1 second. Your inspiratory flow rate is thus ~ 60 lpm during this deep breath. Every breath you take varies in depth and volume, but if you were in respiratory failure you may well require flow rates of this high or more. To be guaranteed a FiO₂ appropriate to your flow demand, a fixed performance device must be used with a flow rate of > 60 lpm to satisfy demand.

A. LOW-FLOW SYSTEMS

The FiO₂ is variable or not fixed.

FiO₂ varies with:

1. Oxygen flow rate
2. Patient’s peak inspiratory flow
3. Patient’s minute ventilation = RR and Tidal Volume

- The deadspace of the nasopharynx or the face mask act as an oxygen reservoir
- Room air is entrained because the gas flow from the oxygen device is insufficient to meet the patient’s peak inspiratory flow requirements.
- They cannot deliver high inspired concentrations of oxygen.

1. Nasal Prongs

- Oxygen flows from the nasal prongs into the patient’s nasopharynx. During inhalation, entrained air mixes with the reservoir of oxygen in the nasopharynx.
- Used to provide low level supplemental oxygen (22 – 44%)
- **Maximum flow should be limited to 6 L/min.** It is not possible to raise the FiO₂ further, due to turbulence, in the tubing and in the airway.
- High flow rates may be uncomfortable and cause dry mucous membranes
- Little effect whether patient is mouth breathing or nose breathing

- 1 lpm of O₂ = ↑ FiO₂ by 4%

  E.g. 1 lpm = 24%              2 lpm = 28%

- Advantage: comfortable, eat and speak
- Disadvantage: FiO₂ is variable by the pattern of breathing.
2. Oxygen Masks

**Simple Mask**
- Delivers 40-60% oxygen at flow rates of 6 – 10 L/min
- A minimum $O_2$ flow rate of 6 L/min is required to prevent rebreathing of exhaled $CO_2$

**Non-Rebreather Mask**
- Delivers $FiO_2$ 80-100%
- A mask with openings on it and a reservoir bag attached
- A minimum $O_2$ flow rate of 12-15 L/min is required to prevent rebreathing of exhaled $CO_2$
- A collapsed reservoir bag indicates inadequate $O_2$ flow
- May be used to transport patients who require > 50% oxygen

**Isolation Mask**
- HI – OX 80 Mask: A solid mask (no holes) with a filter for the exhaled air. There is a valve to prevent exhaled air from entering the reservoir bag.
- USED FOR *** AIRBORNE ISOLATION PATIENTS ***

B. HIGH-FLOW SYSTEMS

The $FiO_2$ is fixed.
- Flows meet or exceed the patient’s peak inspiratory flow
- Consists of an adjustable air-entrainment port, which determines specific oxygen concentrations. Openings in the delivery device become smaller as higher concentrations of oxygen are used (i.e. less entrainment of room air)

1. **Venti – Mask**
- Variable colored connectors ranging from 24 – 50% oxygen concentration.

2. **Nebulizer:** Misty OX nebulizers are used at NYGH.
- $FiO_2$ 33 – 95%
- Used with a flowmeter. Connected to corrugated tubing.
- Can be connected to a tracheostomy mask or face mask.
- If the flow rate is not high enough, the patient may entrain room air and dilute the oxygen concentration.
- The RRT will set up high flow nebulizers and monitor the patient daily and prn.
OXYGEN THERAPY

NEVER SWITCH FROM A HIGH FLOW SYSTEM TO A LOW FLOW SYSTEM WITHOUT CALLING RESPIRATORY THERAPY

MONITORING

Patient:
- Clinical assessment such as signs of respiratory distress, work of breathing, cardiovascular status (e.g. BP, HR)
- Assessment of physiologic variables: PaO$_2$ or SaO$_2$

Equipment: On Wards,
- All oxygen delivery systems $\geq$ 50% will be checked by the RRT at least once a day
- All tracheostomy patients will be checked by the RRT once a day
OXYGEN THERAPY

WHAT ABOUT COPD PATIENTS?

“The Hypoxic Drive Theory”

“If they inhale too much oxygen, they can stop breathing”

We have all heard the buzzwords……..“He’s a Retainer”

Assumption: If you give if too much oxygen to a COPD patient, you will shut down the patient’s hypoxic drive causing them to stop breathing and go into cardiac arrest.

What do you need to breathe?

1. **Central Chemoreceptors** (brainstem, medulla, apneustic center)
2. Effectors: diaphragm, abdominal and intercostal muscles
3. Sensors: **Peripheral Chemoreceptors** (Carotid body)

Control of Breathing

Normally, our stimulus to breathe is in response to an increase in the concentration of CO\(_2\) in the blood. Normally, the only time that oxygen levels stimulate breathing would be if the concentration of O\(_2\) in the blood fell too low. This oxygen stimulus acts as a “back-up” system.

Therefore, CO\(_2\) drives ventilation

- **Central Chemoreceptors** are the major regulators of breathing. Respond to:
  - Hypercapnea (↑CO\(_2\)) and change in pH
  - Hypoxia: No effect on central chemoreceptors

Hypoxia is a *weak* stimulus to breathe (only 10% role in breathing)

- **Peripheral Chemoreceptors** respond to:
  - Hypercapnea (↑CO\(_2\)) and change in pH, and
  - Hypoxia

- Therefore, WE ALL have a hypoxic drive or stimulus to breathe. Part of normal physiology.
- Becomes eliminated when PaO\(_2\) > 170mmHg, and becomes more important when PaO\(_2\) < 55mmHg
- Only some COPD patients develop chronic CO\(_2\) retention. Why?

There is a problem with their central chemoreceptors. They have been exposed to chronically elevated CO\(_2\) for so long that their stimulus to breathe changes from that of a normal patient. They require higher CO\(_2\) levels before they increase their rate of breathing AND they rely on their peripheral chemoreceptors when the O\(_2\) levels are too low, i.e. “hypoxic drive to breathe”.

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In clinical practice, we often assume this applies to ALL COPD patients, even if they are NOT chronic CO\textsubscript{2} retainers.

**How to Manage CO\textsubscript{2} Retainers:**

- **Must treat hypoxemia first!** Correct life threatening hypoxemia
- **Controlled Oxygen Therapy:** Aim for Sp\textsubscript{0}\textsubscript{2} 88 – 92% or PaO\textsubscript{2} 55 – 70 mmHg
- Remember, it is the oxygen level in the blood not the inspired oxygen concentration that the chemoreceptors are sensitive to. PaO\textsubscript{2} NOT FiO\textsubscript{2}
- ∴ Patient needs whatever concentration of oxygen necessary to return PaO\textsubscript{2} 55–70 mmHg
- With seriously hypoxic patients start with 100% oxygen and then work down. NOT the other way around.
- If the patient does start to retain CO\textsubscript{2} or reduce their respiratory drive (rarely), then they need ventilatory support (BiPAP or ventilator).

  “Hypoxia kills quickly, hypercapnia slowly”

- There are only a handful of patients out there that survive on their hypoxic drive, but the first rule must be IF THE PATIENT IS HYPOXIC, GIVE OXYGEN, and then **Call CCRT!**
- If they then develop respiratory depression, deal with this as it happens by supporting ventilation and NOT REDUCING THEIR OXYGEN.