The Fundamentals of Oxygen Therapy

TERRENCE SHENFIELD MS, RRT-ACCS, RPFT, NPS, AE-C

Learning Objectives (1 of 2)

- Describe when oxygen (O_2) therapy is needed.
- Assess the need for O_2 therapy.
- Describe what precautions and complications are associated with O_2 therapy.
- Select an O_2 delivery system appropriate for the respiratory care plan.

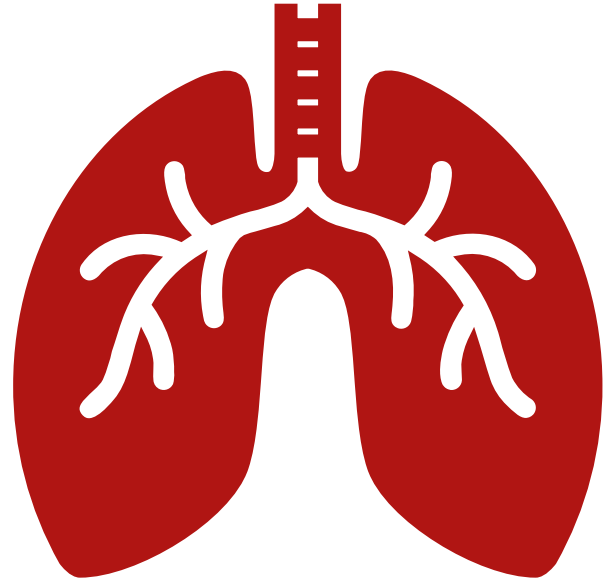
Learning Objectives (2 of 2)

- Describe how to administer O_2 to adults, children, and infants.
- Describe how to identify and correct malfunctions of O_2 delivery systems.
- Assess and monitor a patient's response to O_2 therapy.
- Describe how and when to modify or recommend modification of O_2 therapy.

Testing your skills

- What is hypoxemia?

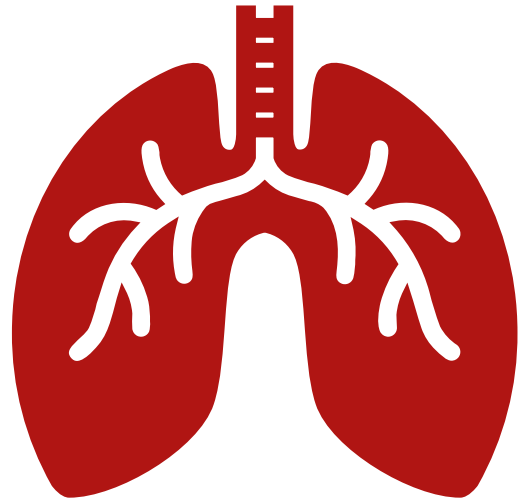
1. Decreased tissue oxygenation
2. Increased tissue oxygenation
3. Low levels of oxygen in the blood
4. High levels of oxygen in the blood



Testing your skills

- What is oxygenation?

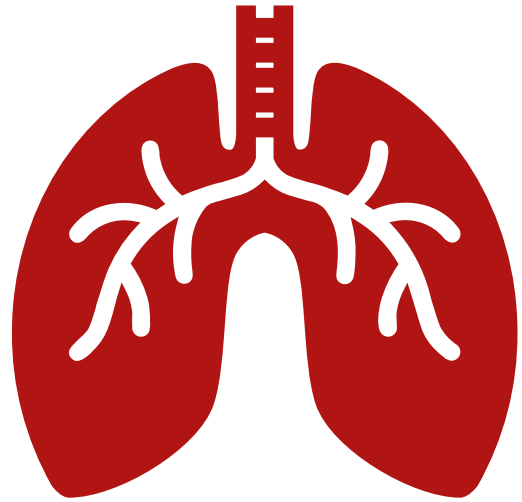
1. Inhalation and exhalation process of the body
2. Oxygen being used for the body
3. The delivery of oxygen to body tissues and cells



Testing your skills

- Which oxygen delivery system is for high flow oxygen?

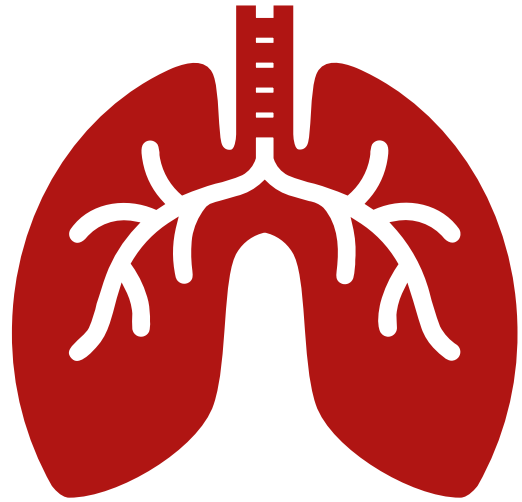
1. Nasal cannula
2. Partial nonrebreather
3. Venturi mask
4. Simple mask



Testing your skills

- Which oxygen delivery system would you use for the lowest flow of oxygen

1. Simple face mask
2. Nonrebreather
3. Nasal cannula
4. Partial nonrebreather



What is this?

What is this?

What is this?

Oxygen Therapy

- The overall goal of O_2 therapy:
  - Maintain adequate tissue oxygenation
  - Minimizing cardiopulmonary work
- Clinical objectives for O_2 therapy:
  - Correct documented or suspected acute hypoxemia
  - Decrease symptoms associated with chronic hypoxemia
  - Decrease the workload hypoxemia imposes on the cardiopulmonary system

Assessing the Need for Oxygen Therapy

Indications

- Documented hypoxemia as evidenced by
  - PaO_2 less than 60 mm Hg or SaO_2 less than 90% in subjects breathing room air
  - PaO_2 or SaO_2 below desirable range for a specific clinical situation
- Acute care situations in which hypoxemia is suspected
- Severe trauma
- Acute myocardial infarction
- Short-term therapy or surgical intervention (e.g., postanesthesia recovery)

Precautions & Contraindications

- Precautions and/or possible complications
  - With FiO_2 greater than 0.5:
    - Absorption atelectasis
      - Wash out of nitrogen and collapsing of airways and air trapping
    - O_2 toxicity
      - The acute toxicity manifests generally with central nervous system (CNS) effects, while chronic toxicity has mainly pulmonary effects
    - Depression of ciliary function may occur

Contraindications

- Carbon dioxide narcosis
  - Excessive CO2 is present in the bloodstream, leading to a depressed level of consciousness. This condition largely results from lung disease, hypoventilation, or environmental exposure.
- Neonates exposed to high levels of oxygen are at risk for developing retinopathy of prematurity
  - Oxygen promotes neovascularization of the retinas and can cause vision loss or blindness
- Oxygen toxicity
  - As the oxygen gets metabolized, some molecules convert to superoxide anions known as hydroxyl radicals, which are human tissue toxic

Indications

- Chronic
  - Chronic obstructive pulmonary disease (COPD)
  - Cystic fibrosis
  - Pulmonary fibrosis
  - ILD
- Acute
  - Sepsis
  - Major trauma
  - Cardiac arrest and during resuscitation
  - Carbon monoxide and cyanide poisonings
  - Transfusion-related acute lung injury (TRALI)

Let's start with basics

- Room air consists of:
  - 21% oxygen
  - 79% nitrogen
  - Trace amounts of other gases
    - Argon
    - Carbon dioxide
    - Neon
    - Helium
    - Methane
    - Hydrogen

Physiology

PO2, SaO2, CaO2 are all related but different.

PaO2 is a sensitive and non-specific indicator of the lungs' ability to exchange gases with the atmosphere.

FIO2 is the concentration of oxygen in the gas mixture

Normal PaO2 decreases with age

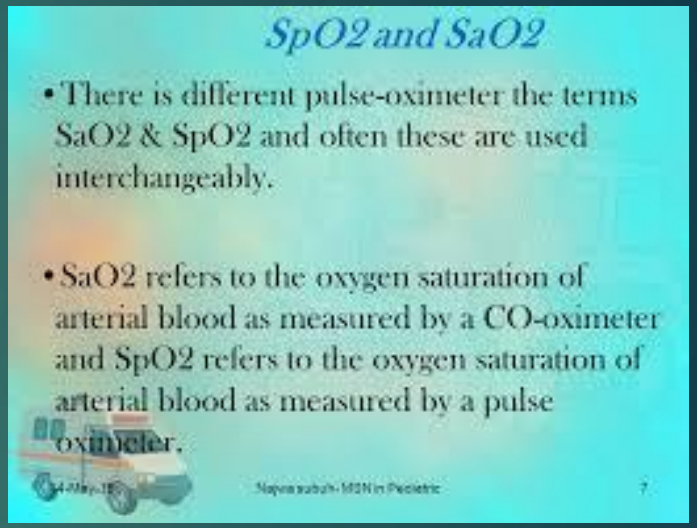
The body does not store oxygen

What is Pa02?

- PaO2, the partial pressure of oxygen in the arterial blood, is determined solely by the pressure of inhaled oxygen (the PIO2), the PaCO2, and the architecture of the lungs
- Normal values
  - Partial pressure of oxygen (PaO2): 75 to 100 millimeters of mercury (mm Hg)

What is SaO2?

- SaO2 is the percentage of available binding sites on hemoglobin that are bound with oxygen in arterial blood.
- Oxygen is transported in the blood in two ways: oxygen dissolved in blood plasma (pO2) and oxygen bound to hemoglobin (SaO2). About 97% of oxygen is bound to hemoglobin while 3% is dissolved in plasma
- The O2 dissociation curve (and hence the SaO2 for a given PaO2) is affected by PaCO2, body temperature, pH and other factors.
- Arterial oxygen saturation
- SaO2 is unaffected by the content of hemoglobin, so anemia does not affect SaO2



What is Ca02?

- CaO2 is arterial oxygen content.
- CaO2 directly reflects the total number of oxygen molecules in arterial blood, both bound and unbound to hemoglobin
- Units for CaO2 are ml oxygen/100 ml blood

$$C_aO_2 = (Hgb * 1.34 * \frac{S_aO_2}{100}) + (0.0031 * P_aO_2)$$

What is Sp02?

- SpO2 stands for peripheral capillary oxygen saturation, an estimate of the amount of oxygen in the blood.
- It is the percentage of oxygenated hemoglobin compared to the total amount of hemoglobin in the blood
- Peripheral oxygen saturation
- SpO2 is an estimate of arterial oxygen saturation
- Not useful in CO2 poisoning
- Decreases with age

Therapy & Diagnosis

- Supplemental O2 is an FIO2 > 21% and is a drug.
- A reduced PaO2 is a non-specific finding.
- A normal PaO2 and alveolar-arterial PO2 difference (A-a gradient) do NOT rule out pulmonary embolism.
  - A normal A–a gradient for a young adult non-smoker breathing air, is between 5–10 mmHg.
- A given liter flow rate of nasal O2 does not equal any specific FIO2.
- Face masks cannot deliver 100% oxygen unless there is a tight seal.
- No need to humidify if flow of 4 LPM or less

Oxygen Delivery Systems

- O_2 delivery systems: design and performance
  - Three basic designs exist
    1. Low-flow systems
    2. Reservoir systems
    3. High-flow systems
- Clinical performance ultimately determines how the device is used
  - How much O_2 can the system deliver?
  - Does the delivered FiO_2 remain fixed or vary under changing patient demands?

Flow Rate (liter/min)	FIO2
1	0.24
2	0.28
3	0.32
4	0.36
5	0.40
6	0.44

Equipment

- Nasal Cannula
  - 1 – 6 LPM
  - FIO2 0.24 – 0.44 (approx 4% per liter flow)
  - FIO2 decreases as Ve increases
- Simple Mask
  - 5 – 8 LPM
  - FIO2 0.35 – 0.55 (approx 4% per liter flow)
  - Minimum flow 5 LPM to flush CO2 from mask
- Venturi Mask
  - Variable LPM
  - FIO2 0.24 – 0.50
  - Flow and corresponding FIO2 varies by manufacturer

Low-Flow Systems: Nasal Cannula

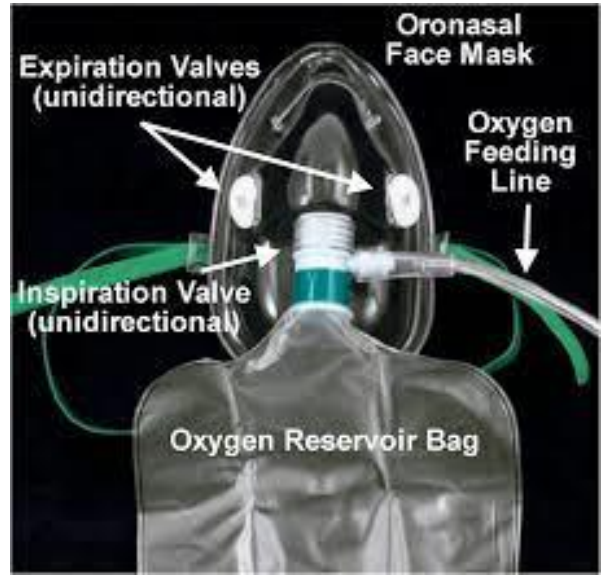
- Delivers FiO_2 of 0.24 to 0.40
- Used with flow rates of ¼ to 8 L/min
- FiO_2 depends on how much room air patient inhales in addition to O_2
- Device is usually well tolerated
- A humidifier is used when the input flow is greater than 4 L/min

Venturi Mask

- Venturi Mask
  - Variable LPM
  - FIO2 0.24 – 0.50
  - Flow and corresponding FIO2 varies by manufacturer

Nonrebreather mask and partial rebreather

- A non-rebreather mask can deliver between 60 percent to 80 percent oxygen at a flow rate of about 10 to 15 liters/minute (L/min)
- They're useful in situations when people have extremely low levels of blood oxygen, since they can quickly deliver oxygen to your blood



MONITORING

- Physical examination for hypoxemia
- Pulse oximetry
- ABG analysis
  - pH
  - pO2
  - pCO2

Physical examination for hypoxemia

- Changes in the color of your skin, ranging from blue to cherry red
- Confusion
- Cough
- Fast heart rate.
- Rapid breathing
- Shortness of breath
- Slow heart rate
- Sweating

Pulse oximetry

- Pulse oximetry is ubiquitously used for monitoring oxygenation in the critical care setting
- Forewarning the clinicians about the presence of hypoxemia, pulse oximeters may lead to a quicker treatment of serious hypoxemia and possibly circumvent serious complications

Important Normal Values on ABG			
pH	7.35	-	7.45
pCO_2	35 mmHg	-	45 mmHg
pO_2	75 mmHg	-	100 mmHg
HCO_3	22 mEq/L	-	26 mEq/L
O_2 Sat	Greater than 95%		

ABG analysis

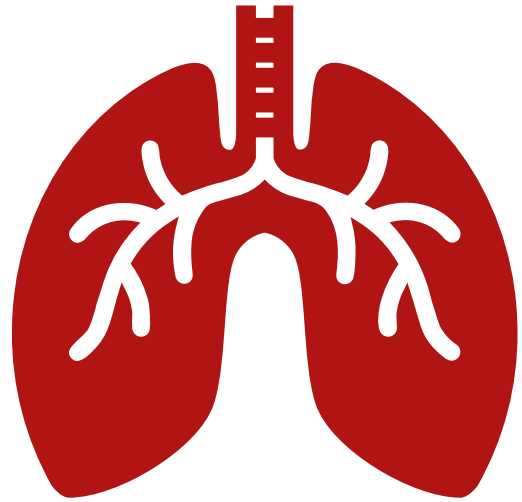
- The arterial blood gas (ABG) analysis is a lab test that measures the acid-base balance (pH) and oxygenation of an arterial blood sample, usually obtained by direct arterial puncture

Complications of Oxygen therapy

1. Oxygen toxicity
2. Depression of ventilation
3. Retinopathy of Prematurity
4. Absorption atelectasis

O_2 Toxicity

- Primarily affects lung and CNS.
- 2 factors: PaO_2 & exposure time
- CNS O_2 toxicity (Paul Bert effect
  - Tremors, twitching, convulsions
- Lung
  - Uncontrollable coughing
  - Hemoptysis
  - Dyspnea
  - Rales



How much O2 is safe?

100% - not more than 12hrs
80% - not more than 24hrs
60% - not more than 36hrs

Goal should be to use lowest possible FiO2 compatible with adequate tissue oxygenation

Indications for 70% - 100% oxygen therapy

- Resuscitation
- Periods of acute cardiopulmonary instability
- Patient transport

Nasal Cannula

- Concentrations of O_2 by nasal cannula
  - 1L/min = 24%
  - 2L/min = 28%
  - 3L/min = 32%
  - 4L/min = 36%
  - 5L/min =40%
  - 6L/min = 44%

PEARLS of Wisdom

Low flow devices are not sealed to face or nares

Oxygen mixes with room air

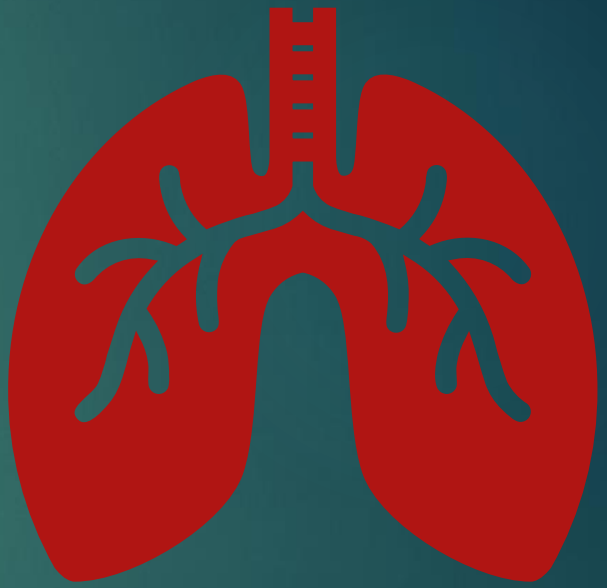
Oxygen delivered greater than 4L/min should be humidified to prevent nasal mucosa drying

Supplemental oxygen improves oxygenation but does not change ventilation

Testing your skills

- What is hypoxemia?

1. Decreased tissue oxygenation
2. Increased tissue oxygenation
3. Low levels of oxygen in the blood
4. High levels of oxygen in the blood



Testing your skills

- What is oxygenation?

1. Inhalation and exhalation process of the body
2. Oxygen being used for the body
3. The delivery of oxygen to body tissues and cells

Testing your skills

- Which oxygen delivery system is for high flow oxygen?

1. Nasal cannula
2. Partial nonrebreather
3. Venturi mask
4. Simple mask

Testing your skills

- Which oxygen delivery system would you use for the lowest flow of oxygen

1. Simple face mask
2. Nonrebreather
3. Nasal cannula
4. Partial nonrebreather

Summary

- Know how to use oxygen
- Know your devices and limitations
- Always monitor your patient
- Know how to escalate care being delivered
- Know the contraindications

References

- 1. Urner, M., Calfee, C. S., & Fan, E. (2021). Titrating Oxygen Therapy in Critically Ill Patients. JAMA, 326(10), 911-913.
- 2. Cournoyer, A., Grand'Maison, S., Lonergan, A. M., Lessard, J., Chauny, J. M., Castonguay, V., ... & Daoust, R. (2021). Oxygen therapy and risk of infection for health care workers caring for patients with viral severe acute respiratory infection: a systematic review and meta-analysis. Annals of emergency medicine, 77(1), 19-31.
- 3. Christensen, M. A., Steinmetz, J., Velmahos, G., & Rasmussen, L. S. (2021). Supplemental oxygen therapy in trauma patients: An exploratory registry-based study. Acta Anaesthesiologica Scandinavica.