

The Fundamentals of Oxygen Therapy

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Learning Objectives (1 of 2)

- ▶ Describe when oxygen (O₂) therapy is needed.
- ▶ Assess the need for O₂ therapy.
- ▶ Describe what precautions and complications are associated with O₂ therapy.
- ▶ Select an O₂ delivery system appropriate for the respiratory care plan.



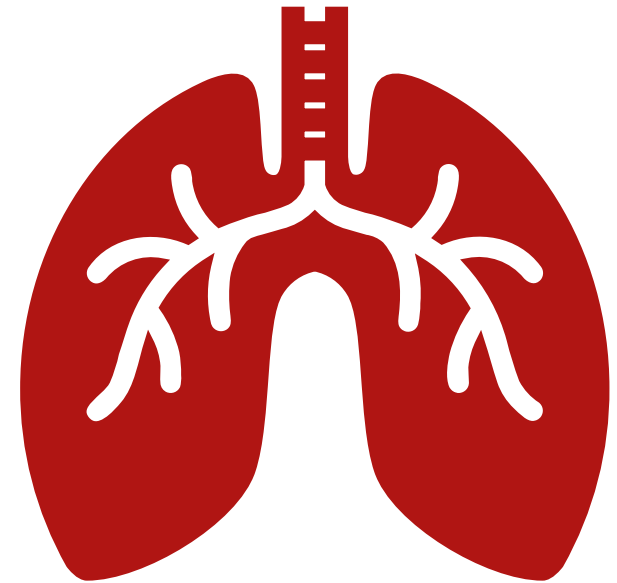
Learning Objectives (2 of 2)

- ▶ Describe how to administer O₂ to adults, children, and infants.
- ▶ Describe how to identify and correct malfunctions of O₂ delivery systems.
- ▶ Assess and monitor a patient's response to O₂ therapy.
- ▶ Describe how and when to modify or recommend modification of O₂ therapy.



Testing your skills

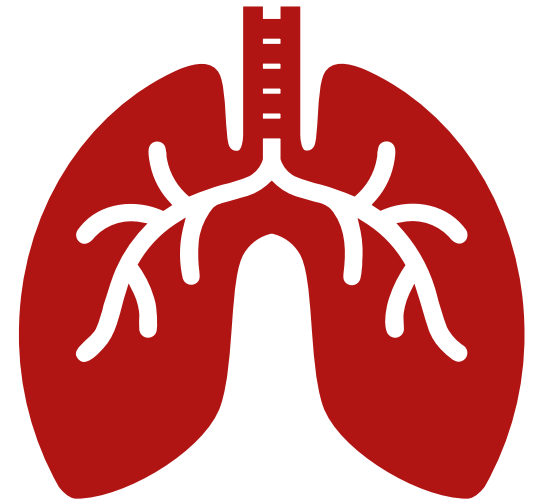
- ▶ What is hypoxemia?
 1. Decreased tissue oxygenation
 2. Increased tissue oxygenation
 3. Low levels of oxygen in the blood
 4. High levels of oxygen in the blood



Testing your skills

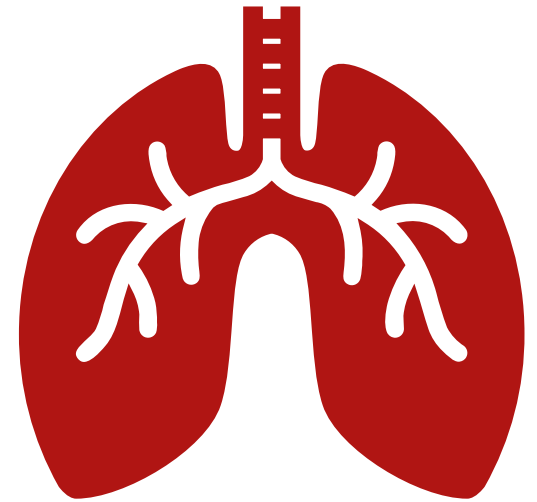
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- ▶ What is oxygenation?
 1. Inhalation and exhalation process of the body
 2. Oxygen being used for the body
 3. The delivery of oxygen to body tissues and cells



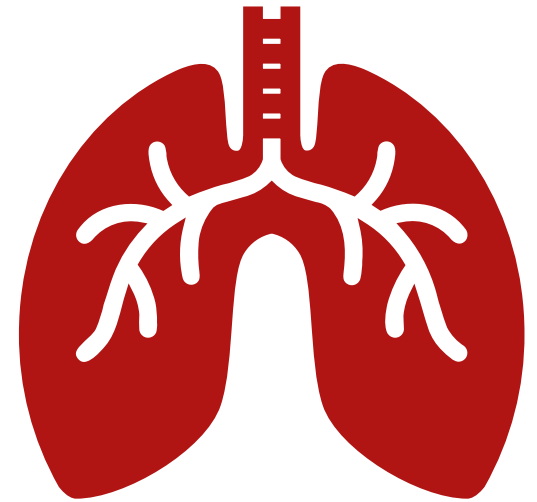
Testing your skills

- ▶ 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 O₂ therapy:
 - ▶ Maintain adequate tissue oxygenation
 - ▶ Minimizing cardiopulmonary work
- ▶ Clinical objectives for O₂ 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
 - ▶ PaO₂ less than 60 mm Hg or SaO₂ less than 90% in subjects breathing room air
 - ▶ PaO₂ or SaO₂ 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

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PO_2 , SaO_2 , CaO_2 are all related but different.

PaO_2 is a sensitive and non-specific indicator of the lungs' ability to exchange gases with the atmosphere.

FIO_2 is the concentration of oxygen in the gas mixture

Normal PaO_2 decreases with age

The body does not store oxygen



What is PaO₂?

- ▶ PaO₂, the partial pressure of oxygen in the arterial blood, is determined solely by the pressure of inhaled oxygen (the P_IO₂), 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

SpO₂ and SaO₂

- There is different pulse-oximeter the terms SaO₂ & SpO₂ and often these are used interchangeably.
- SaO₂ refers to the oxygen saturation of arterial blood as measured by a CO-oximeter and SpO₂ refers to the oxygen saturation of arterial blood as measured by a pulse oximeter.



4-11-15
Najma Zubin - MSN in Pediatric



What is CaO₂?

- ▶ 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

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



What is SpO₂?

- ▶ 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

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- ▶ O₂ 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 O₂ can the system deliver?
 - ▶ Does the delivered FiO₂ remain fixed or vary under changing patient demands?



Flow Rate (liter/min)	FI _{O2}
1	0.24
2	0.28
3	0.32
4	0.36
5	0.40
6	0.44



Equipment

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- ▶ Nasal Cannula
 - ▶ 1 – 6 LPM
 - ▶ FIO₂ 0.24 – 0.44 (approx 4% per liter flow)
 - ▶ FIO₂ decreases as V_e 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 $\frac{1}{4}$ 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

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Venturi Mask

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

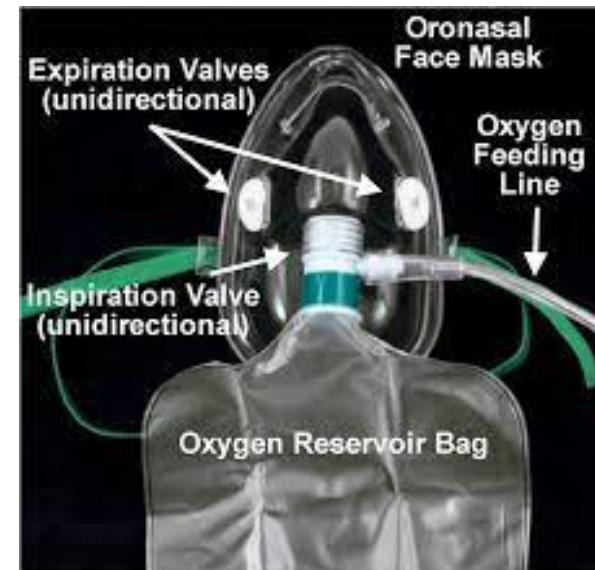
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Nonrebreather mask and partial rebreather

- ▶ 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

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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



Hypoxemia: Symptoms,
Causes, Treatment



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



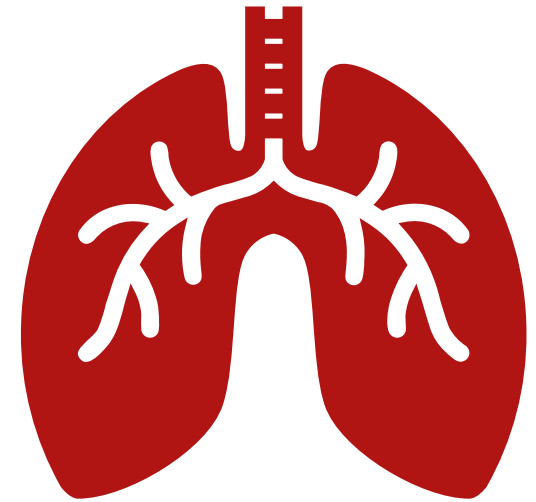
Complications of Oxygen therapy

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



O₂ Toxicity

- ▶ Primarily affects lung and CNS.
- ▶ 2 factors: PaO₂ & exposure time
- ▶ CNS O₂ 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 O₂ 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

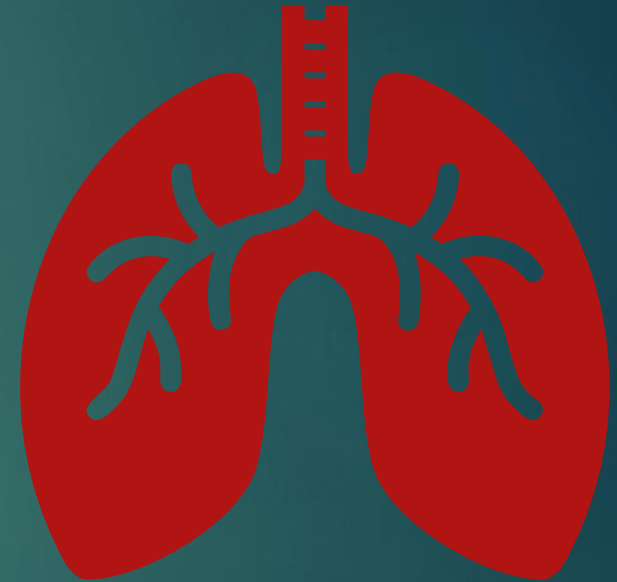
Supplemental oxygen improves oxygenation but does not change ventilation



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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*.

