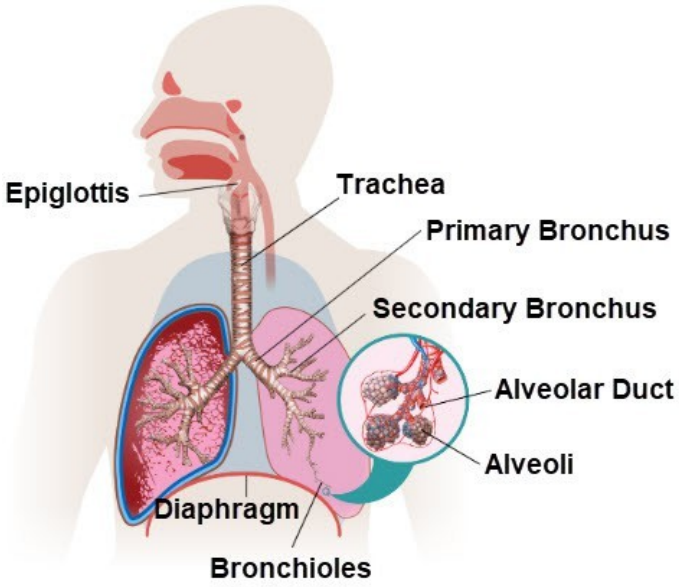
NR 283-Week 7 Edapt

Gas Exchange

Gas exchange is the transportation of oxygen (O_2) into the blood and cells and carbon dioxide (CO_2) from the blood and cells. For gas exchange to occur at the cellular level, ventilation, or the movement of O_2 into and CO_2 out of the lungs, must occur. The respiratory system works in synchrony to ensure that inhaled air spends enough time within the alveoli of the lung for this gas exchange to occur. Gas exchange is a complex system of timing and chemistry that guarantees the body the gases it needs to survive. **Gas exchange** occurs in the **alveoli,** but does not occur in the trachea, bronchioles, or diaphragm.

The upper respiratory tract (upper airway) consists of the nose, mouth, sinuses, pharynx (upper section of the throat), epiglottis, and larynx (voice box). Only the epiglottis is labeled on the image.

The lower respiratory tract consists of the trachea (windpipe), bronchial tubes, and lungs.



Gas Movement

Based on fluid dynamics and physics, gases travel between the alveoli and the capillaries by moving from areas of high concentration and pressure to an area of low concentration and pressure. This is because of the principles of diffusion and changes in pressure during exhalation and inhalation. The pressure and concentration gradient are always changing but, generally, the force produced at higher pressures can move the gases in certain directions.

Gas Exchange Process

Gas exchange is how oxygen moves from the air that we breathe to the cells as carbon dioxide moves from the cells into the air we breathe.

The Need for Oxygen

Oxygen is vital for cellular metabolism. Hemoglobin transports oxygen. Oxygen is exchanged for carbon dioxide in the alveoli of the lung. Each hemoglobin molecule is limited by the amount of oxygen it carries.

Oxygen pressure is not used in the transfer of gases. Both oxygen and carbon dioxide move from an area of higher pressure and concentration to an area of lower pressure and concentration by diffusion. A higher altitude makes oxygen exchange harder.

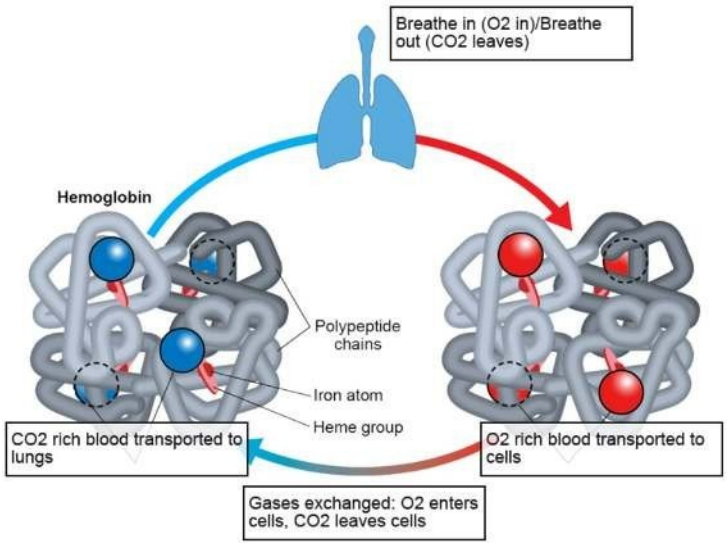
Gas Exchange Explained

Gas Exchange

Definitions:

- Transfer of gases between environments
- Lungs and cells of the body are two common places for exchange
- Gas exchange happens in the kidneys and cells through cellular respiration
- Gases need transport to site of exchange
- For gas to be exchanged, it needs transportation. Imagine a car, moving people from one place to another. When the car gets to the destination, it picks up other people and returns them home.
- Just like a car, hemoglobin transports carbon dioxide (waste from cells) to the alveoli and exchanges it for oxygen that has been inhaled.
- When a person inhales, oxygen is sucked into the lungs.
- After the exchange, hemoglobin (part of a red blood cell) takes oxygen to the cells.
- Gas exchange can occur in all types of different body systems. One example of gas exchange is what occurs between the red blood cell and the alveoli in the lungs through a process of pressure and diffusion. Not matter where it occurs, the process is similar.

Gas Exchange Process



1. Breathe in (O_2 in)/Breathe out (CO_2 leaves)
2. O_2 rich blood transported to cells
3. Gases exchanged: O_2 enters cells, CO_2 leaves cells
4. CO_2 rich blood transported to the lungs

Causes of Impaired Gas Exchange

Many different things can impact gas exchange. Here are just a few to consider:

- not enough oxygen in the environment (suffocation)
- too much carbon dioxide in the environment (carbon dioxide poisoning)
- partial or full blockage between the mouth and the alveoli (choking)
- blockage of gas exchange by another substance or chemical (drowning, infection)
- not enough hemoglobin to carry oxygen (anemia)
- blood clots in the capillaries or veins (pulmonary emboli)
- difficulty exhaling because of trapped air (asthma or chronic obstructive pulmonary disease)
- muscles used to breathe are too weak (spinal cord injury, myasthenia gravis)

A clot in the left leg produces an embolus (a free-floating blood clot) that travels through the venous system to the inferior vena cava. The embolus passes through the right side of the heart, through the pulmonary artery, and lodges in a smaller vein within the lungs blocking the flow of blood.

Reasons for Hypoxia

When something does go wrong, there are two main reasons this happens. There is not enough oxygen being collected (ventilation) or something is preventing the oxygen from getting to its destination (perfusion).

Ventilation Problem

- limited or no oxygen in the environment (limited oxygen in surrounding environment)
- not enough pressure to pull the oxygen into the lungs (muscle weakness)
- something is blocking the airway (foreign object or tongue)

Perfusion Problem

- not enough hemoglobin to transport the oxygen to the body (anemia or blood loss)
- hemoglobin cannot carry enough oxygen (carbon monoxide poisoning)
- hemoglobin is unable to carry oxygen (deformed red blood cell)
- atherosclerosis or embolus decreasing blood flow

Ventilation Versus Perfusion

Ventilation problem: Anything stopping oxygen from getting into the lungs is a ventilation problem.

- No air: If there is low or no oxygen in the surrounding air, then breathing is compromised.
- Muscle weakness: The diaphragm and chest muscles are responsible for ventilation.
- Tongue blocking airway: Blockage of an airway is a ventilation problem.

Perfusion problem: Anything stopping oxygen from getting to the cells through the blood is a perfusion problem.

- Blood loss: Lack of hemoglobin causes a lack of oxygen transported to tissues.
- Carbon monoxide poisoning: Carbon monoxide can bind to hemoglobin strongly, especially when there is a large amount of it.
- Sickle cell disease: A deformed red blood cell cannot carry oxygen to tissue.

Gas Exchange Balance

The conclusion to any gas exchange impairment is progressively increased hypoxia. The brain, which uses a large amount of oxygen, will start to fail. Symptoms of this include confusion, lethargy, weakness, fatigue, decreased oxygen saturation, and loss of consciousness.

The body tries to maintain homeostasis by:

- increasing the respiratory rate
- increasing the heart rate
- increasing the blood pressure

- changing the pH of the blood
- forcing respiratory muscles to work harder

Impaired Gas Exchange

When gas exchange is impaired, the body compensates. **Decreased** oxygen levels in the arterial blood signal the body to **increase** respirations, blood pressure, and heart rate so quicker gas exchange can occur.

Risk Factors for Gas Exchange

Gas exchange can be impacted by many external things.

High Altitude

- Less oxygen and less pressure.
- Results in lower rate of gas exchange.
- The higher the altitude, the less oxygen and the less pressure there is to promote oxygen/carbon dioxide gas exchange. Supplemental oxygen is often used when we are at high altitude, OR pressure is added to our vehicle to compensate (i.e., airplane).

Pollution

- 21% of the air has oxygen.
- Particulates impair oxygen flow to blood.
- Pollution is another thing that can impact gas exchange. Only 21% of our air has oxygen. When particulates are inhaled, hey can “clog the filter” and impair the movement of oxygen into the blood.

Lifestyle

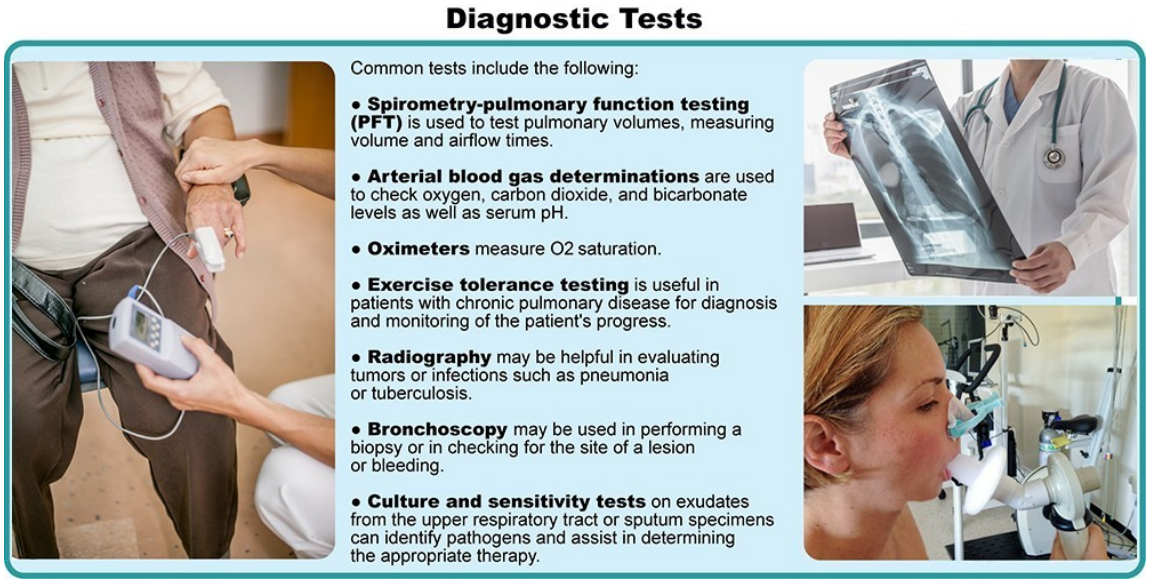
- Smoking causes tar buildup in lungs.
- That leads to altered gas exchange.
- Lifestyle is also an important factor that could affect gas exchange. Cigarette smokers routinely inhale thousands of chemicals within smoke, causing a buildup of tar and other elements within the lung tissue, leading to altered gas exchange.

Diet

- Affects gas exchange.
- Low iron means insufficient oxygen carbon dioxide exchange.
- Diet affects gas exchange as well. People who have low iron intake lack enough iron to transport the exchanged oxygen from the lungs or carbon dioxide from the body.

- In addition, there are some genetic conditions that cause chronic anemia (low or abnormal red blood cell counts) which can cause further problems transporting gases.

How to Test Gas Exchange



Treating Impaired Gas Exchange

Treatments

Treatment	Effect
Avoid inhaling irritants and maintain good ventilation	Reduces inflammation and infection
Current immunizations	Prevents infection
Humidify air	Moist mucosa resists damage Thins and removes secretions
Moderate exercise	Improves lung function and circulation
Breathing and coughing	Improves lung expansion and removes secretions
Chest physiotherapy	Removes thick secretions and reduces infections
Oxygen	Improves oxygen supply to all body cells

Drugs

Drug	Effect
Decongestants	Vasoconstriction in nasal mucosa, reduces edema
Expectorants	Thins respiratory secretions for easier removal
Antitussives	Reduces cough reflex
Antihistamines	Blocks H1 receptors to reduce allergic response
Analgesics	Reduces pain
Antimicrobials	Prophylaxis and treatment of infection (sputum culture and sensitivity)
Bronchodilators	Stimulates beta-2 adrenergic receptors to open bronchioles
Glucocorticoids	Antiinflammatory, antiallergenic

Surgical Interventions

Intervention	Function
Thoracentesis	Removal of excess fluid from the pleural cavity prevents atelectasis
Tracheotomy	Incision into the trachea below the larynx to permit air intake
Surgery	Removes tumor, abscess, or damaged tissue

Preventing Gas Exchange Problems

There are some great strategies that can prevent or reduce the likelihood of a gas exchange problem. Here are a few basic prevention actions.

- Do not smoke and, if you do, stop.
- Do at least 20 to 30 minutes of aerobic exercise three to five times per week.
- Get vaccinated against respiratory illnesses (e.g., pneumococcal pneumonia, COVID-19, and influenza).
- Avoid exposure to high levels of indoor and outdoor pollution.
- Use safety equipment and follow safety guidelines when working with hazardous chemicals (e.g., cleaning products and insecticides).
- If you have asthma or allergies, see your healthcare provider to obtain treatment.
- Learn to swim and do not swim alone.
- Always take small bites and chew your food completely.

Prevention Strategies

Walking a mile at a fast pace is getting aerobic exercise, one of the best forms of exercise for gas exchange. Getting an influenza shot yearly will help decrease the incidents of influenza and the possibility of gas exchange problems. Reading warnings and following safety guidelines for hazardous chemicals can reduce gas exchange problems.

Smoking a cigar and going out when there are high levels of pollution puts someone at risk for gas exchange problems.

Gas Exchange and Age

- As we age, our lung function decreases. There is less elasticity in the alveoli and there can be a decrease in the volume of air we can breathe. The surface area of alveoli lessens, causing a decrease in gas exchange. Exercise is a great way to help preserve as much function as possible. Stopping cigarette use, no matter how old you might be, will also reduce the speed of lung decline. The change in lung decline is due to metaplastic cellular changes reversing once the irritating chemicals are no longer present.
- Family history is also important. Some conditions are genetic in origin. For example, cystic fibrosis, which can cause excess lung secretion, can be diagnosed later in life. Pulmonary emboli (blood clots in the lungs) can also be caused by inherited blood-clotting disorders.

Altered Gas Exchange

- Cough, chest pain, shortness of breath, and current smoking history all suggest a gas exchange problem.
- Elevated oxygen saturations are not possible. Oxygen saturation is normally between 92 and 100%. They do not go higher than 100%.
- Altered gas exchange can be caused by a blockage of air traveling in, poor oxygen diffusion across the capillary into the red blood cell, blockage of blood traveling away from the lung, the inability of carbon dioxide to diffuse into the alveoli, or the inability to exhale.
- Because carbon dioxide does not diffuse from the hemoglobin to the cells of the body, this cause is incorrect.
- Prolonged gas exchange problems are most likely to cause low oxygen saturation, confusion, and loss of consciousness as oxygenated blood is not getting to the brain or peripheral tissue.

- Red skin is not common with gas exchange problems. Improved cognitive function can result from improved, not problematic, gas exchange.
- Actions that can reduce gas exchange problems in the future include learning to swim, smoking cessation, air purifiers, getting vaccinated against respiratory illnesses, and avoiding pollution.

Homeostasis

Increasing respiration, changing blood pH, and forcing respiratory muscles to work harder are all homeostatic mechanisms that can improve gas exchange.
Increasing digestion or relaxing the diaphragm does not improve gas exchange.

Ventilation and Perfusion

A **ventilation** problem is when there is not enough oxygen being collected. A **perfusion** problem is when something is preventing oxygen from getting from the alveoli to its destination. **A blood clot** is a perfusion problem and **choking** is a ventilation problem.

Gas Exchange Problems

Gas Exchange Problem	Cause
Suffocation	Not enough oxygen in the environment
Choking	Partial or full blockage between the mouth and the alveoli
Anemia	Not enough hemoglobin to carry oxygen
Pulmonary emboli	Blood clots in the capillaries or veins
Myasthenia gravis	Muscles used to breathe are too weak

Age-Related Changes

Less elasticity in the alveoli, decreased airway volume, and decreased (not increased) surface area of the alveoli are age-related changes.
Cigarette smoking is an active choice and not age-related. Increased respiration is not an age-related change.

Pneumonia

Introduction to Pneumonia

Pneumonia is an infection of the alveoli in the lungs. There are many different organisms that can cause the infection; however, the results are very similar. Inflammatory response causes edema, fluid, and exudate to fill the alveoli and prevent the exchange of