RESPIRATORY BLOCK

Physiology Team~ 430

5th Lecture

Gas Exchange

Done By :

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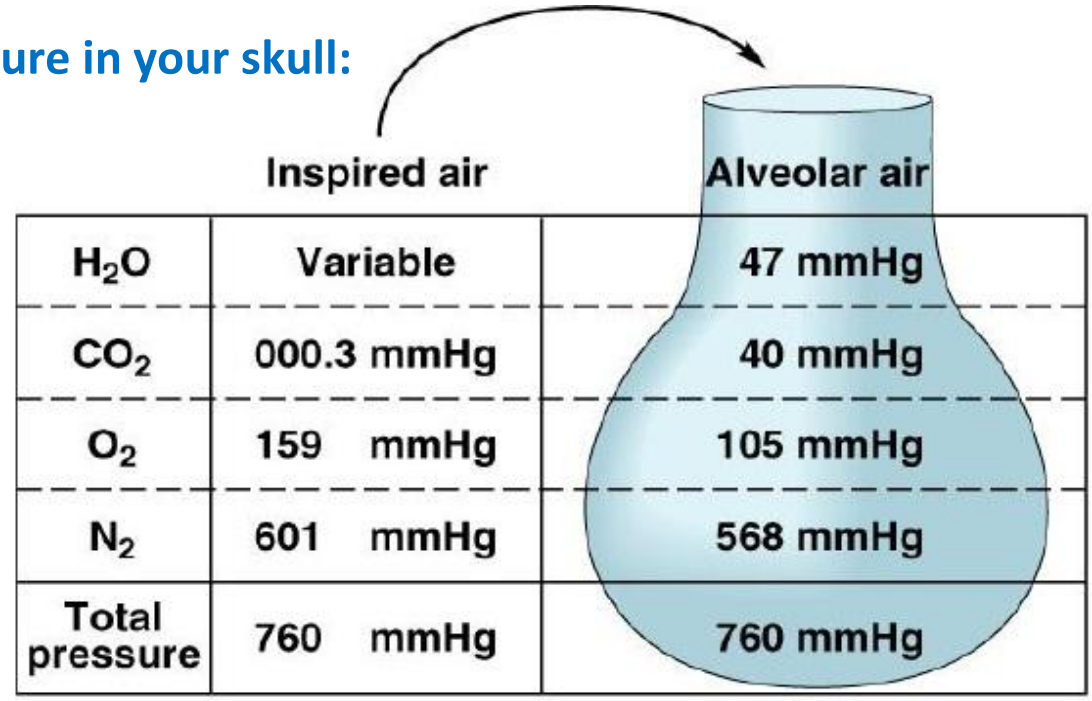
- After ventilation of the alveoli with fresh air the next step is the process called Diffusion of oxygen and carbon dioxide. (Gas exchange)
- Gas exchange in the lungs occurs across an estimated 300 million alveoli.
- Their enormous number provides a large surface area for diffusion of gases.
- The rate of diffusion of each of these gases is directly proportional to the pressure caused by this gas alone which is called the partial pressure of the gas
- Pressure is caused by the constant impact of kinetic moving molecules against a surface.
- Respiratory membrane, through which gas exchange occurs, is composed of an alveolar membrane and a capillary membrane. Both capillary and alveolar membranes are only one cell-layer thick, so that the "air blood barrier" is only two cell membranes thick .

- Alveolar ventilation (AV) : is the volume of new air entering the alveoli and gas exchange areas per minute.
- Gas exchange : Diffusion of oxygen and carbon dioxide
- The diffusion gas molecules are moving randomly and have kinetic energy . so , it exerts its own partial pressure in the same way (symbols : P_{O2} , P_{CO2} and P_{N2})
- ↑ partial pressure → ↑ diffusion gases

Partial pressure

- Atmosphere pressure is 760 mm Hg .
- Oxygen is 21% of atmosphere . So, P_{O_2}= 760 × 0.21 = 159 mm Hg . This mixes with "old" air already in alveolus , therefore (P_{O_2} = 105 mmHg.)
- Carbon dioxide is 0.04% of atmosphere . So, P_{CO_2} = 760 × 0.0004 = 0.3 mm Hg . This mixes with high CO2 levels from residual volume in the alveoli therefore (P_{CO_2} = 40 mmHg.)

- **Put this picture in your skull:**



H_2O	Variable	47 mmHg
CO_2	000.3 mmHg	40 mmHg
O_2	159 mmHg	105 mmHg
N_2	601 mmHg	568 mmHg
Total pressure	760 mmHg	760 mmHg

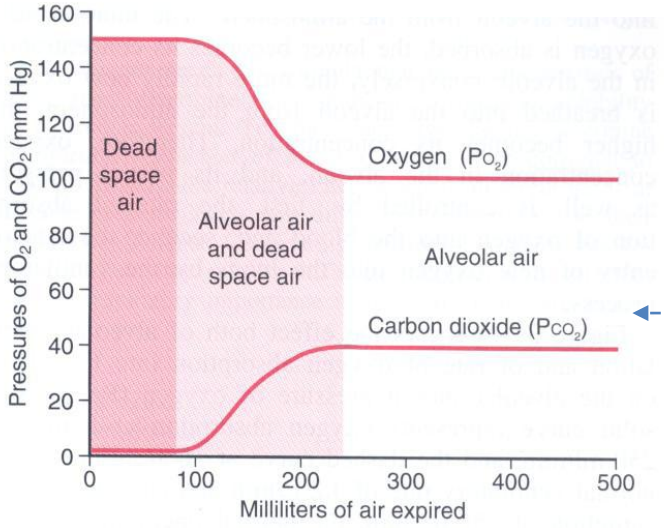


FIGURE 39-6

Oxygen and carbon dioxide partial pressures in the various portions of normal expired air.

O_2 and CO_2 concentration in various potions of normal expired air

PO_2 in various parts of the circulation

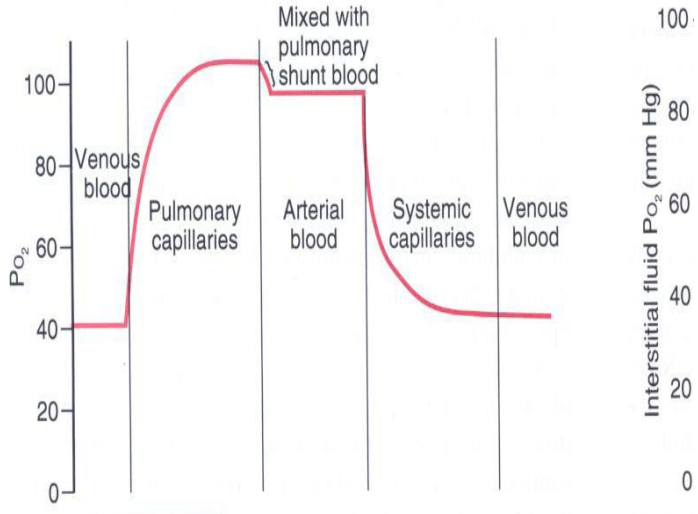


FIGURE 40-2

- **Composition of air :**

- **Inhaled air :**
  79% = nitrogen
  20 % = oxygen
  Trace = CO_2

- **Exhaled air :**
  79% = nitrogen
  16 % = oxygen
  4% = CO_2

توجد نسبة من O_2 في Exhaled air , لذا نستطيع إنعاش المصابين

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$$\underline{D} \propto \frac{\Delta P \times A \times S}{D \times \sqrt{MW}}$$

$\underline{D}$: Diffusion rate
ΔP : Pressure difference
A : Cross sectional area of pathway
S : Solubility
D : Distance of the diffusion
MW : Molecular weight

- **Factors affecting diffusion across the respiratory membrane :**
- **Effective external and internal respirationdepends on :**

1- ↑Thickness of the membrane → ↓ rate of gas transfer,
e.g. in edema.

2- ↓ surface area of the membrane → ↓ rate of gas transfer,
e.g. if part of the lung is removed.

3-↑partial pressure difference →↑rate of diffusion.

4- ↑diffusion coefficient of the gas → ↑ rate of gas transfer.

- $\frac{S}{\sqrt{MW}}$ called diffusion coefficient

- ↑ Solubility →↑ Diffusion coefficient
- ↑ √Mwt. of the gas → ↓ Diffusion coefficient
- Diffusion coefficient of :
- O_2 = 1.0 .. CO_2 = 20.0 .. N_2 = 0.53

- O_2 has lower molecular weight than CO_2
- O_2 would be expected to diffuse 1.2x faster
- CO_2 24x more soluble than O_2

Net result:

CO_2 diffusion approx 20x faster than O_2 diffusion , because of its high solubilityin tissue fluids.

- **Diffusion capacity of the respiratory membrane:**

is the volume of gas that diffuses through the membrane each minute for a pressure difference of 1mmHg

- Diffusing capacity for oxygen = 21ml/min/mmHg

(هذا اذا كان فرق الضغط واحد ،،)

Even if the oxygen pressure difference across the respiratory membrane is 11mmHg , Diffusing capacity for oxygen : 11x21= 230ml oxygen diffusing through the membrane each minute

- During rest tissues consume 250 ml O2 /min

- **Diffusing capacity for carbon dioxide:**
  It diffuses 20 times greater than oxygen due to greater diffusion coefficient which is 20 times that for oxygen
  (معامل الانتشار لثاني اكسيد الكربون اكبر ، لان ذوبانيته أعلى من الاكسجين)
- **Diffusion capacity for carbon dioxide = 400ml/min/mmHg**
- **During exercise 1200 to 1300ml/min/mmHg**

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Notice that :

- **Alveolar air does not have the same concentration of gases as does inspired air:**

  Is because :

  -- The alveolar air is only partially replaced by atmospheric air with each breath.

  -- Oxygen is constantly being absorbed from the alveolar air.

  -- Carbon dioxide is constantly diffusing from the pulmonary blood into the alveoli.

  -- Dry atmospheric air that enters the respiratory passages is humidified even before it reaches the alveoli.

من الطبيعي يكون بينهم اختلاف ،، وهذا الشي اساسا راجع لاختلاف قيم الـ Partial pressure

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- **Rate at which alveolar air is renewed by atmospheric air:**

new air with each breath entering the alveoli =350ml.

(with each new breath ,, we take Tidal volume "500" but we said that there is a dead space volume ,, So :
500 – 150 = 350)

This slow replacement of the alveolar air is important to prevent sudden changes in gaseous concentrations in the blood.

- **Oxygen concentration and pressure in the alveoli is controlled by :**

1-The rate of absorption of oxygen into the blood

2-The rate of entry of new oxygen into the lungs by ventilator process.

- **At resting condition 250ml of oxygen enter the pulmonary capillaries/min at ventilator rate of 4.2 L/min,**
- **During exercise 1000 ml of oxygen is absorbed by the pulmonary capillaries per minute, the rate of alveolar ventilation must increase four times to maintain the alveolar P_{O_2} at the normal value of 104mmHg**

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- **Carbon dioxide concentration and pressure in the alveoli:**
  - **Normal rate of carbon dioxide excretion of 200ml/min, at normal rate of alveolar ventilation of 4.2L/min.**
  - **The alveolar P_{CO_2} increases directly in proportion to the rate of carbon dioxide excretion, and it decreases in inverse proportion to alveolar ventilation.**

GooD LucK