Lecture 10

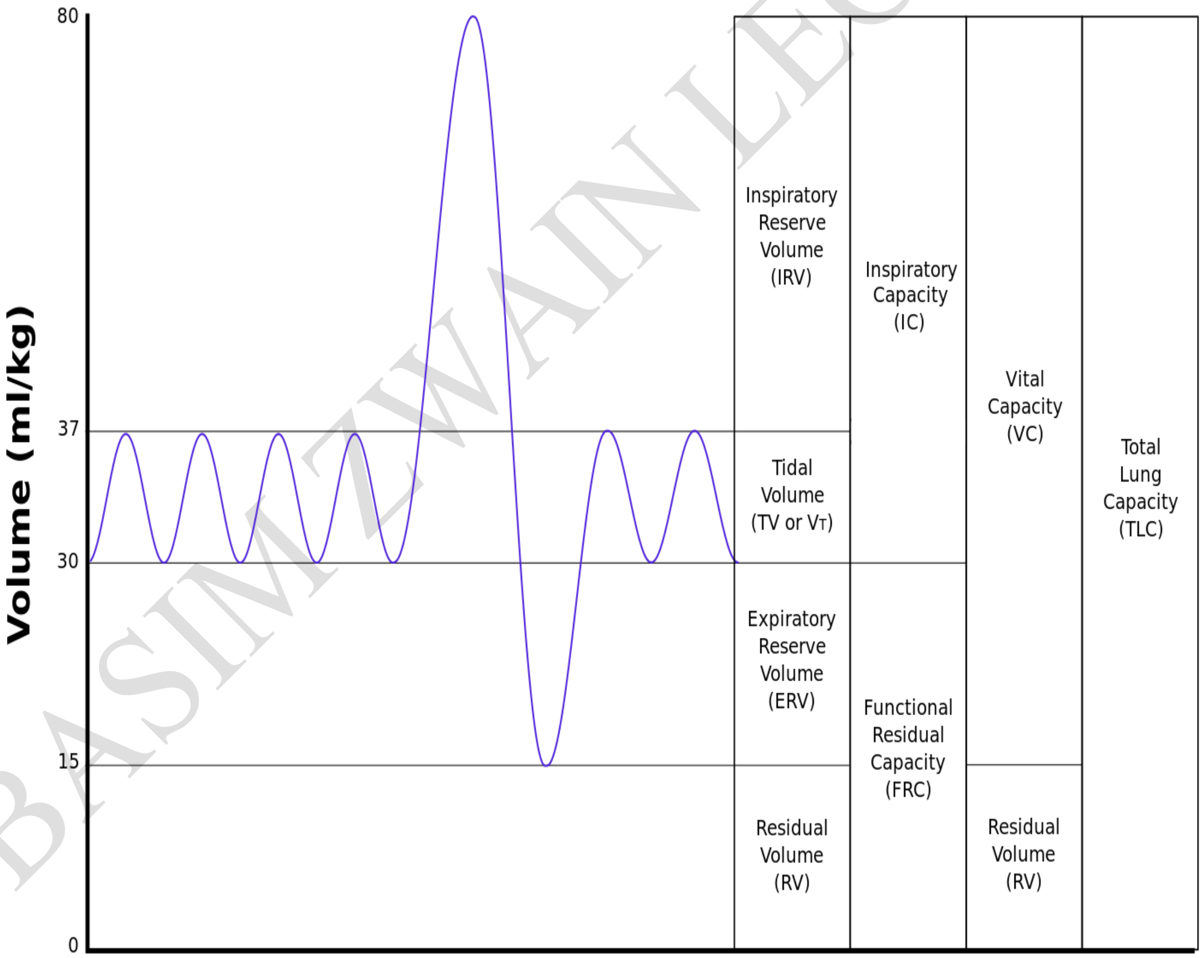
RESPIRATION

Respiratory system

The main function of the respiratory system is to take in oxygen and give out carbon dioxide. It also regulates acid-base balance and heat and participates in phonation and vocalization.

Ventilation of the lungs

The air in the lungs has been divided into several volumes and capacities. Tidal volume (**V_T**) is the volume of air inspired and expired with each normal quiet breath. It is about 500 ml. Vital capacity (**VC**) is the maximum expiration after maximum inspiration. It is about 4600 ml.



These volumes and capacities are in normal young male but, they are about 20%-25% less in female. They are also lower in older and shorter subjects.

The normal respiratory rate is 12-15 breaths per minute (**BPM**) which is also called the respiratory frequency (**RF**).

V_T *** RF = pulmonary ventilation** (or **minute respiratory volume**)

pulmonary ventilation represents the total amount of new air moved into the respiratory passages each minute. Pulmonary ventilation is about 6000-7500ml/min:

500 ml x 12 BPM = 6000 ml/ min. **500 ml x 15 BPM = 7500 ml/min.**

But, not all of the 500 ml of V_T reaches the respiratory zone (which involves: respiratory bronchioles, alveolar atria, alveolar sacs and alveoli). Instead, about 150 ml of air is wasted inside the conductive zone (*also called the dead space which involves: nasal cavity, nasopharynx, larynx, trachea, bronchi, bronchioles down to the terminal bronchioles*) and never contribute to gas exchange. This is called the dead space volume (V_D).

So, the alveolar ventilation (V_A) represents the total amount of air that reaches the respiratory zone each minute which is about 4200-5250 ml/min:

$$V_A = RF * (V_T - V_D)$$

= 12 x (500 - 150) = 4200 ml/min. **15 x (500 - 150) = 5250 ml/min**

Transport of oxygen and carbon dioxide between alveoli and tissue

Gas exchange in pulmonary capillaries is called external respiration, while gas exchange in tissue capillaries is called internal respiration. Normally, about 97% of O_2 is transported in chemical combination with hemoglobin (Hb) in RBC and only 3% is transported in dissolved state in the water of plasma and cells while CO_2 is transported in three forms:

- In the form of bicarbonate (HCO_3^-)………………………………………. 70%
- In combination with Hb and some other plasma proteins………………. 23%
- In dissolved state……………………………………………………….... 7%

Oxygen-hemoglobin dissociation curve

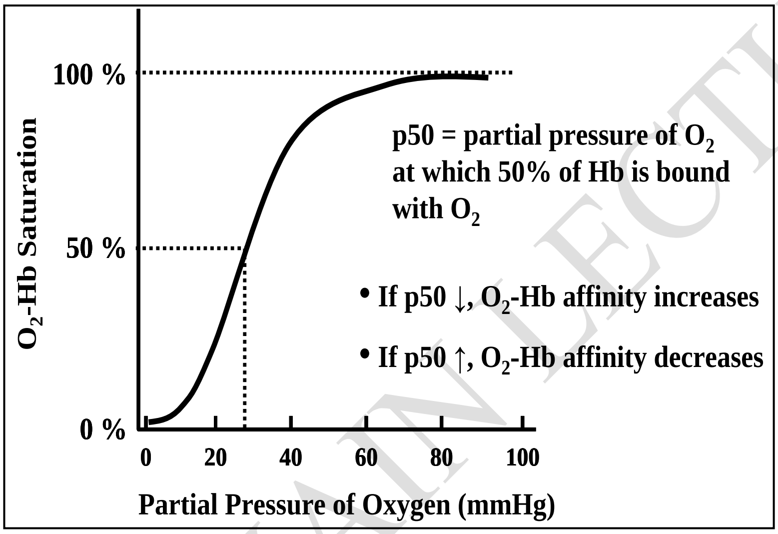
When PO_2 is high, this will favor loading of Hb with O_2 (increased percentage of saturation of Hb with O_2) and vice versa, when PO_2 is low, this will favor unloading of Hb from O_2 (decreased % of saturation of Hb with O_2). The relation between PO_2 and percentage of saturation of Hb with O_2 is drawn as a curve called O_2-Hb dissociation curve:

PO_2 = 95 mmHg→ 97% saturation

PO_2 = 40 mmHg→ 75% saturation

The following factors cause right shift of the curve:

1. Decreased pH, 2. Increased CO_2, 3. Increased temperature, 4.Increased DPG (Diphosphoglycerate)



This right shifting in tissue capillaries favors unloading of O_2 to the tissues. The opposite factors occur in pulmonary capillaries and cause left shift of the curve which favors loading of O_2 from the lungs. Presence of large amounts of Hbf (fetal Hb) in the blood is another factor that causes left shift of the curve which favors loading of O_2 from the maternal circulation to the fetal circulation. Fetal Hb has more affinity to combine O_2 than adult Hb.

Control of breathing (regulation of respiration)

Control of breathing is either **neural** or **chemical**. Neural control is either **voluntary** or **involuntary**. Chemical control is either **central** or **peripheral**.

-Voluntary neural control is direct control from cerebral cortex. It regulates certain voluntary activities like breath holding, hyper- and hypo- ventilation.

-Involuntary neural control

1. The respiratory center in the brain stem which is responsible for autonomic respiration.
2. The pulmonary receptors which are responsible for pulmonary reflexes.
    a. Stretch receptors (stop lung overinflation)
    b. Irritant receptors: (responsible for cough and sneeze reflexes)
    c. J-receptors (sensation of dyspnea due to congestion)

-Central chemical control (chemosensitive area beneath the hypothalamus)

-Peripheral chemical control (chemoreceptors at aortic and carotid bodies)

<u>Clinical considerations: Hypoxia</u>

Low level of PO2 anywhere is called hypoxia. Hypoxia in the blood is called hypoxemia. There are four types of hypoxia:

1. Hypoxic hypoxia: The most common type (there is a decline in Pa_{O2}).
2. Anemic hypoxia: Pa_{O2} may be normal, but HbO_2 is declined due to anemia or CO poisoning.
3. Stagnant hypoxia: Pa_{O2} and HbO_2 may be normal, but blood flow is reduced.
4. Histotoxic hypoxia: Pa_{O2}, HbO2, and blood flow may be normal, but the tissue cannot utilize O_2 due to enzymatic inhibition caused by poisons or drugs e.g. cyanide poisoning.