Al- mustaqbal University College
Anesthesia Techniques Department
First stage /medical physics
Third lecture by Asst. Lecturer Fatema Sattar

Lecture 4:

Physics of the lung and Breathing

We breath 6 liters of air per minute (this is also about the Volume of blood the heart pumps each minute). Men breathe 12 times per minute at rest while women and infants breathe 20 times, 60 times per minute respectively.

The air we inspire about (80 % N_2 + 20 % O_2), the air we expire (80% N_2+16 % O_2 + 4%CO_2).

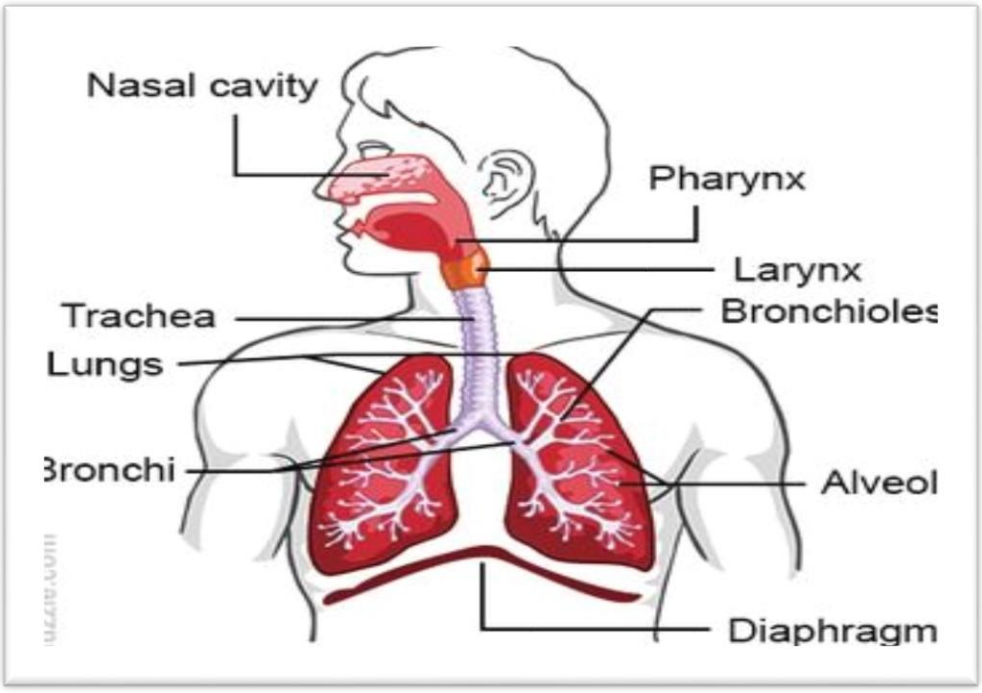
The lungs have large convoluted shape with surface area about 80m^2.

-The Air Ways

The air passes through windpipe (trachea), each bronchus divide multiple times (about 15 times) until it reach to a sac like structure called alveoli of 0.2mm diameter and 0.4 μm wall thickness, each alveolus surrounded by blood capillary as shown in figure (1). So O2 can diffuse from alveolus into RBC and CO2 diffuse from blood into air in the alveolus.

1 Large chunks removed by cough

2 Small particles carried upward to the mouth by millions of small hairs or cilia of 0.1mm long that have wave like motion. Each cilia vibrates about 1000 times a minute. The mucus moves 1-2 cm/min (1 mile/week). Cilia as escalator system of trachea. It takes 30 min for Particle of dust to be cleared out of the bronchi and trachea into throat where it is expelled or swallowed.



-How Blood and Lungs Interact

About (1 Liter) of blood supply the lungs, but only 70 ml is in the capillaries of the lungs getting O2.

The transfer of O2 and CO2 into and out of blood is controlled by law of diffusion. Molecules diffuse from region of higher concentration to lower concentration until concentration uniform.

A molecule of O2 diffuse faster than CO2 because of its smaller mass. The lungs are not emptied during expiration, during normal breath the lungs retains about 30% of their volume at the end of each expiration.

-Measurement of Lungs Volumes

During normal breathing we inhale 500 cm^3 of air with each breath. If a person cough or sneeze hard the velocity of air in the trachea can reach the velocity of sound in air.

This high velocity can cause partial collapse of air ways because of Bernoulli Effect. In coughing to dislodge foreign object, this partial collapse increases air velocity and increase the force on foreign object.

-Physics of the Alveoli

The alveoli like millions of small interconnected bubbles, have tendency to get smaller due to surface tension of unique fluid lining. This lining called surfactant.

The absence of surfactant in the lungs of some new born infant is the cause of respiratory distress syndromes (RDS) called hyaline membrane disease which causes death.

To understand the physics of alveoli we have to understand physics of bubble. The pressure inside bubble is inversely proportional to the radius and directly to the surface tension.

$$P = 4 \gamma / R$$

Figure (2) shows P-V curves for human lungs when p needed to then reinflate the lungs.

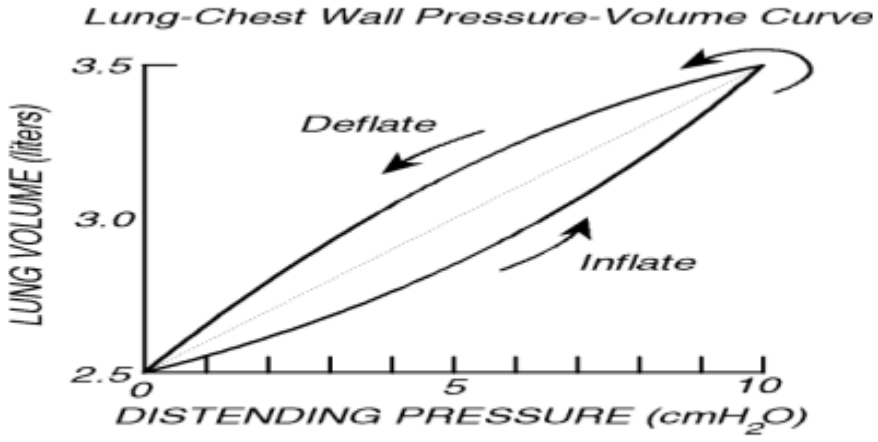


Figure 2: P-V curves for human lungs

-Two Forces Keep Lungs from Collapsing

1- Surface tension between lungs and chest

2- Air pressure inside the lungs.

Since each lung is its own sealed compartment, it is possible to collapse one lung only. This is done by inserting a hollow needle between ribs and allowing air to

flow into intrathoracic space, the air trapped in the space is gradually absorbed by tissue and lung expand to normal over few weeks, sometimes lung collapses spontaneously with no known cause. The lungs returns to normal as the air is absorbed into surrounding tissues. Since both lung and chest are elastic we can represent them with springs.

-Air Way Resistance

During inspiration the forces on airways tend to open them further, during expiration the forces tend to close the airways and restrict flow.

Most of resistance in the upper airway passages. %10 of Rg is in the terminal airways (bronchioles and alveoli) do not affect air way resistance until they are far advanced.

-Physics of Common Lung Diseases

Emphysema the division between alveoli break down produces large lung spaces, this destruction of lung tissue reduces the springiness of lungs. The lungs become more complaint, small change in pressure produces larger than normal change in volume.

-Emphysema Produces two changes

1- The lungs become flabby and expands

2 -The tissues do not pull very hard on the airways permitting the narrowed airways to collapse easily during expiration.

In asthma due to increasing airway resistance, some of resistance is due to swelling (edema) and mucus in the smaller airways but much of it is due to contraction of smooth muscles round the large air ways.

Fibrosis of lungs, the membranes between alveoli thicken. This has two effects:

1 the compliance of the lungs decreases

2 The diffusion of O2 into capillary decreases

Homework:

1- Why the molecule of O2 diffuse faster than CO_2?

2- Why the lungs are not emptied during expiration?