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ch-7 محاضرة

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Ch.7

# The physics of lungs and breathing

*** Function of Lungs & Breathing :**

1. Exchange of $O_2$ & $CO_2$ Between the blood and air.
2. Keeping PH (acidity) of the blood constant.
   "When we do work PH increase "$CO2_2+H_2O \rightarrow H_2CO_3$""
3. Heat exchange between the body and atmosphere.
4. Fluid balance of the body by warming and moistening the air we breath. in (inspire)
5. Voice production.
6. Removing the dust particles stuck to the moist lining of various air ways.

*** Breathing Rate:**

1. we breath ≈ 6 liters of air per min.
2. Men breath ≈ 12 times / min at rest.
3. Women breath ≈ 20 times / min at rest.
4. Infants breath ≈ 60 times /min at rest.

*The air we inspire is about ≈ 80% $N_2$ and 20% $O_2$

- and Expired air is about 80% $N_2$, 16% $O_2$ and 4% $CO_2$
- we breathe about (10) Kg (22 lb) of air each day.

## 7.1. THE AIRWAYS

The principal air passages into the lungs are shown in Fig. 7.2. Air normally enters the body through the nose where it is warmed (if necessary), filtered, and moisturized. The moist surfaces and the hairs in the nose trap dust particles, bugs, and so forth. During heavy exercise, such as jogging, air is breathed in through the mouth and bypasses this filter system. The air then passes through the windpipe (trachea). The trachea divides in two (bifurcates) to furnish air to each lung through the bronchi.

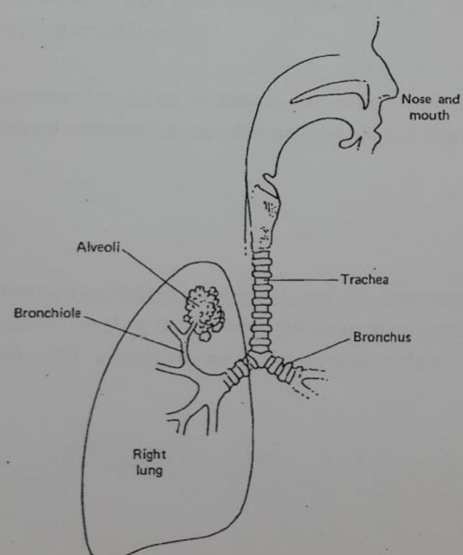


**Figure 7.2. A schematic diagram showing the principal air passages into the lungs.**

* The air wayes :

1.the noise :Air is warmed ,filtered and moistened (moisturized) the moist surfaces and hairs, which trap particles and dirt.

2. the trachea: A wind pipe that the air passes through goes to a lung.

3. the bronchi : Two divisions from the trachea. Each bronchus go to a lung.

4.Bronchinles: Each bronchus divides and redivides 15 times into smaller branches call bronchioles.

5. Alveoli: Air s ace 30 million at birth ,300 million at age 8 years and more, beyond this age the number of stays relativity constant but the alveoli increase in diameter.

Alveoli which are like small interconnected bubbles are about 0.2 mm in diameter and half a wall's only 0.4 micrometer thick , the expand and control during breathing.

They surrounded by blood, so that $O_2$ can diffuse from the alveolus into the red blood cells and $Co_2$ can diffuse from the blood into the air in the alveoli.

* There are two processes involved $O_2$ and $Co_2$ exchange in the lung :

1.perfusion (P) : getting the blood to the pulmonary capillaries bed.

2.Ventilation (V) : getting the air to the alveolar surface.

— perfusion
— ventilation

*There are three P-V, areas in the lung :

1.Areas with good .P. good V. which accounts over 90% of the total volume of normal lung.
2. Areas with poor P. good . V. where a blood flow to part of a lung is blood by a clot.( a pulmonary embolism )
3. Areas with good P. poor V. where air passages in the lunges are obstructed as in pneumonia .

Partial Pressures of $O_2$ and $CO_2$ :
The behavior of the gases (Air exchange by diffusion) obeys to the Dalton's Law of partial pressures:
(The total pressure of different gasses is the sum of the pressures of each would exert when it alone occupied the contained)
Partial pressure =% (gas)* ( atmospheric - partial pressure of water vapor) In The lung →at 37 $C^0$& 100% relative humidity, the partial pressure of water vapor =47 mm Hg,
Atmospheric pressure= 760mm Hg } Table 7.1

**Table 7.1. The Percentages and Partial Pressures of $O_2$ and $CO_2$ in Inspired, Alveolar, and Expired Air**[a]

| | % $O_2$ | $pO_2$ (mm Hg) | % $CO_2$ | $pCO_2$ (mm Hg) |
|---|---|---|---|---|
| Inspired air | 20.9 | 150 | 0.04 | 0.3 |
| Alveolar air | 14.0 | 100 | 5.6 | 40 |
| Expired air | 16.3 | 116 | 4.5 | 32 |

[a] It is assumed that the inspired air is dry and the expired air is saturated, $pH_2O = 47$ mm Hg.

P = 760 mmH

**Henry Law :** it' state the solubility of gases in liquids "The amount of gas Which a liquid will dissolve directly proportional to the partial pressure of the gas

$o_2$ →is not very soluble in blood or water .

→ it' diffuses faster than a molecule of $co_2$ because of its Smaller mass & higher $Po_2$ .

$co_2$ → is larger than that $o_2$ _ molecule , which actually slow the rate of diffusion , because of low $Pco_2$ & larger mass .

On other hand , the $co_2$ is ≈ 25 times more soluble in liquids than the $o_2$ so that the net effect is that the $co_2$ diffuses about times more rapidly in aqueous liquids than does $o_2$ .

I lit of blood can hold =2.5 cm of $o_2$ (100Hg)

**Combination of $o_2$ With Hb :**

Because of the low solubility of $o_2$ in the blood most of the $o_2$ combine with Hb in the blood red cells to be carried to the boy cells .

The Hb leaving lungs≈ 97% saturate with $o_2$ at $Po_2$ 100 mmHg $o_2$ dissociate from Hb and diffuse into the cells because of their low $Po_2$ environment . Fig 7-6

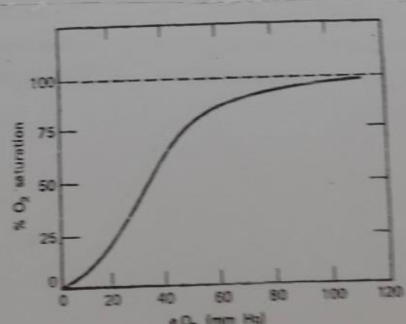


Fig 7-6

The dissociation of $O_2$ from Hb dependent on :

1. $PCo_2$ in the cells :
2. The pH (acidity) (in red blood cells.)
3. The temperature :
4. $Po_2$ of the tissue (cells).

* Under resting condition the venous blood return to the heart with 75% of its load of $O_2$ because it is not needed by the tissues :

* During exercise, $PCo_2$ , pH, (acidity) and temperature are all increased which permit Hb to give most of its $O_2$.

* In addition , the body can increase the blood flow three times, working muscles, which results in $O_2$ supply of 10 times more than they consume at rest.

## $Co_2$ Transporting

Most of $Co_2$ remains in the blood after it have left the lunge ($PCO_2$=40mmHg). The $Co_2$ levels in the blood are maintained fairly constant by the breathing rate.

*The rate of $Co_2$ out part to $O_2$ in take is called Respiratory exchange ratio (Respiratory quanteut) R>1.

*At each normal breath ≈ 50 $cm^3$ of fresh air ($Po_2$ 150mmHg) mixed with ≈ 200 $cm^3$ of stalc air in the lung t result in alveolar air with $Po_2$ ≈ 100mmHg .

## Co poisoning (Carbon monoxide) :

1.CO molecules attach with Hb nearly about 250 times more tightly than $O_2$.
2.Do not easily dissociate in the tissue.
3.Occupy places in Hb normally used to transport $O_2$ .
4.CO inhibits the release of $O_2$ from Hb
so even a small amount CO can seriously reduce the $O_2$ to the tissue.

## Measurement of lung volume

The lung has various volumes and capacities. The volume of the lung versus time (ie ) which record it on a graph .these volumes and capacities can be summarized as follows (which is shown by the graph) : Figure 7.8

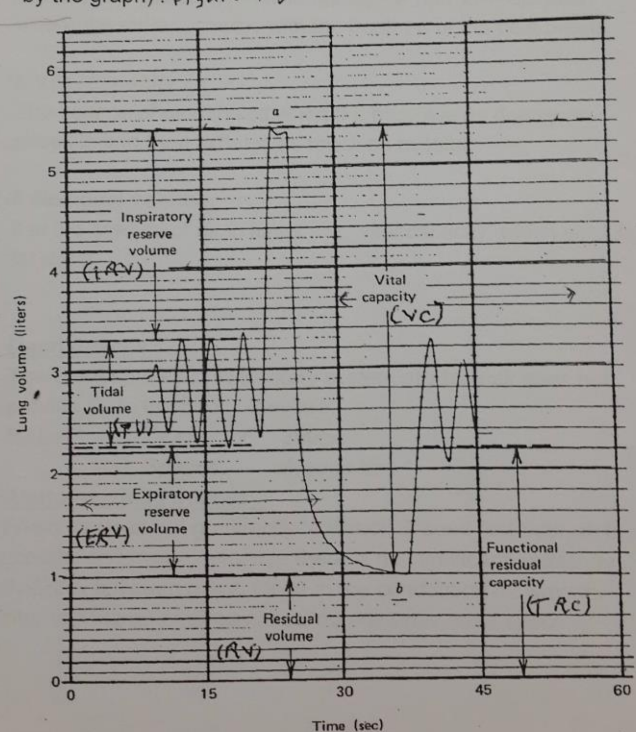


**Figure 7.8.**
**various volumes and capacities of the lungs. Note that during the maximum expiration**

**1.Tidal volume at rest :**

It is the volume of air inhaled with each breath during normal breathing at rest (~500 $cm^3$ ).During heavy exercise the tide volume is considerably large .

**2. Inspiratroy reserve volume :**

It is the additional air taken at the end of inspiration , which is possible with some effort to further fill the lungs with air.

**3.Expiratory reserve volume** :

It is the additional expired air, which can be forced out of the lunge at end of normal expiration.

**4.Functional residual capacity (FRC) :**

It is the air remaining in the lungs after a normal respiration where the stille air mixes with the fresh air of the next breath.

**5.Vital capacity :**

The volume of air exhaled when the breath is as deeply as possible and then exhaled as much as possible.

**6.Residual volume** :

It is the amount of air in lungs after vital capacity, which is ~ 1 lit for adult.

**Dead Spaces :**

There are spaces in respiratory system at which air does not provide $O_2$ to the body . they are:

$500cm^3$ = $150cm^3$ + $350cm^3$

A.D. Spaces alveolar air

**Anatomic dead spaces :**

Fresh air does not go directly to alveoli .it goes first through the conduction airway . because there is no significant exchange of $O_2$ & $Co_2$ between gas & blood in the conducting air way, the internal volume of airway is called anatomic dead space .

**Physiological (alveolar) dead space :**
it is the un used alveolar volumes, in which alveolar capillaries are not perfuse with blood , and $O_2$ is not absorbed in the alveoli.

**Airway diseases test :**
*The maximum rate of expiration after a maximum inspiration is a useful test for obstructive airway diseases where the flow rate sometimes decrease with excessive expiratory effect . During the maximum expiration the out flow is rapid at first : the last 5% takes longer than the first 95% .

*A normal person can expire nearly 70% of his vital capacity in 0.5 sec , 85% at 1 sec , 94% in 2 sec , 97% in 3 sec.

**Pressure airflow Volume relationship in the lung**
*the lungs of a healthy individual need small P to cause air to flow into or out of them, which is few cms of $H_2o$ as in fig (9.7)

*the increase pressure and decrease air flow for a patient with narrowed airway during expiration and increases air flow into or out of the normal lung.

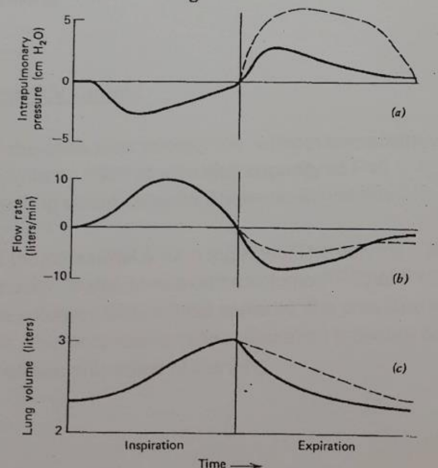


**Figure 7.9.** Typical pressures (*a*), flow rates (*b*), and lung volumes (*c*) during quiet respiration for a normal individual (solid line) and a patient with a narrowed airway (dashed line). Note the increased pressure and decreased flow rates during expiration due to the narrowed airway.

**The pressure Volume curve :**

The esophegus the persure between lungs and chest wall ( intraplcural or ) the pressure in the esophagus can be measured with a pressure gauge which in normally (-10mmHg) due to the elasticity of the lungs . Fig - 7.12

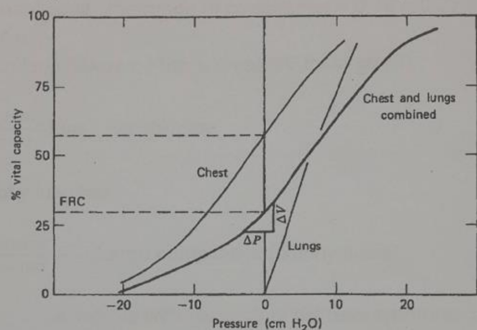


**Figure 7.12.** **The *P-V* curves for the chest alone, the lungs alone, and the chest and lungs combined.**

**From P.V Curve :**

1.if the chest wall (alone) : i.e. without interaction with lung the volume = 2/3 of total vital capacity at P=0
The lUng would collapse &have no air volume.

2.if the chest wall & lung together :The volume =30% of vital capacity ( come to relaxation volume FRC) at P=0 ).
The volume= 60% of vital capacity, the pressure = +10cm , $H_2$o , this pressure is called relaxation pressure &is produced by elastic properties of the lung .

**Compliance is an important physical characteristic of the lung**

Compliance is change in volume produced by small change in pressure

- $C = \frac{\Delta V}{\Delta P} = \frac{\text{change in volume}}{\text{change in pressure}} = \frac{liter}{cm\ H2O}$

- *in normal adult , the range of compliance = 0.18 – 0.27 (lit /cm. $H_2o$ )
- * A Stiff lung (fibrotic ) has a small ΔV for large ΔP.

$C = \frac{small\ \Delta V}{large \Delta P}$ =Low compliance

- *A flabby lung has :

$C = \frac{large \Delta V}{small \Delta P}$ = Large compliance (emphy sema)

note

a. infants with respiratory distress syndrome have lungs with low compliance.

b. in some disease such as ,the emphysema increase . (compliance increases )

**Physics of the alveoli :**

*the alveoli are physically like millions of small interconnected (like bubbles). The alveoli lining is an unique fluid called surfactants which is necessary for a lung to work properly, due to the surface tension (γ) of this fluid .

* the pressure inside the alveoli can be calculation due to (Laplase Law ) (which is applied on bubble ) p=4 γ/r where r is the radius of alveolus.

*the surface tension of the surfactant is not constant because the surface area of the alveolus is variable during breathing .

**Airway Resistance (Ra) :**

Depend on 1- the dimension of airway (the tube)

2- the viscosity of gas

Ra $= \frac{\Delta P}{fr}$ Were $f$ r is the flow rate=$\frac{\Delta V}{\Delta t}$

for typical adults $R_a = 3.3$ cm $H_2o$ (liter/sec

Time Constant (Tc) : Tc=$R_a$C=$\frac{\Delta P}{(\frac{\Delta V}{\Delta t})}$ × $\frac{\Delta V}{\Delta P}$

$R_a$ C = time consistant of lungs is related to the airway risistance ($R_a$) and the Complinance (C).