PASSION ACADEMIC TEAM

YU - MEDICINE

Sheet# 3 - PHYSIOLOGY

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Lec. Title : Lung Volume & Capacities

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RESPIRATORY SYSTEM

LUNG VOLUMES AND CAPACITIES

- What is the residual volume?
- It’s the minimal air volume after forced expiration.

- What is the clinical significant of existence of residual volume?
- To determine the time of death in still birth infants.

- The perforation (hole) of the lung or chest wall leads to disrupt equilibrium of pressure between the atmosphere (0) and the plural pressure (-4), this is called pneumothorax, which is the entering of air in plural cavity.
- The Cure is by inducing a negative pressure in the pleural cavity by suctioning the air out of the pleura. (Suctioning = Negative pressure)

- lung capacity is addition of two or more volumes.
- lung volumes can be measured by a spirometer

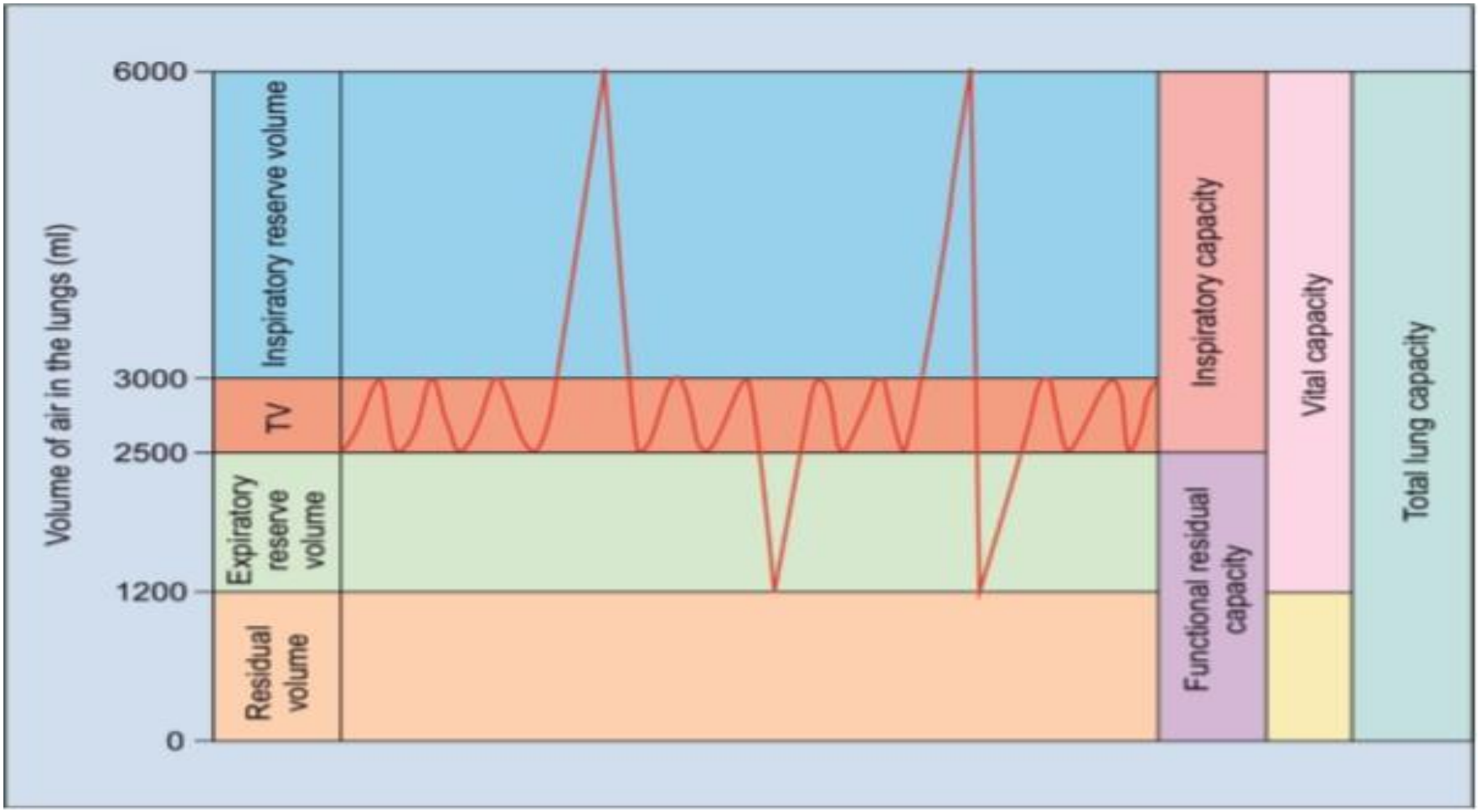
- a spirometer consists of an Air filled drum floating in a water bath
- we need volumes to calculate their capacities
- Because the lung cannot be completely empty, we cannot measure all the volume.
- Some volumes are impossible to measure using a spirometer so we use another technique.

- For example: residual volume cannot be measured using a spirometer
- So, any capacity containing residual volume in its components cannot be calculated as we need a residual volume,
- Functional residual capacity and the total lung capacity need residual volume, so it’s impossible to determine these capacities with spirometer.

- Residual volume of older people is more than in young people, which means residual volume increase with age due to increase the compliance.

Static Lung Volumes and Capacities

There are four lung volumes and four lung capacities



Lung Volumes and Capacities

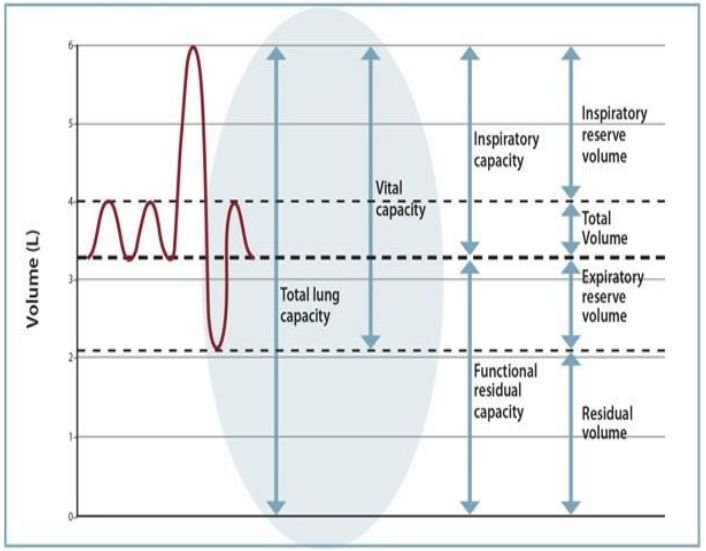
THE LUNGVOLUMES:

1. Tidal volume (TV). This is the volume of air that either inspired or expired in a single breath cycle during normal resting quiet breathing (eupnea). Its average is 500 ml.
    - About 150 ml of this volume fills the airways from the nose and mouth down to the respiratory bronchioles and this volume does not take part in gas exchange. This is called anatomical dead space.
    - The remaining volume, i.e. 350 ml is available for alveolar ventilation.

2. Inspiratory reserve volume (IRV). It is the volume of air that can be inhaled by a maximum inspiratory effort over and beyond the normal tidal volume. It is about 3000 mL (range 2000–3200 mL).
3. Expiratory reserve volume (ERV). It is the extra volume of air that can be exhaled by the maximum forceful expiration over and beyond the normal tidal volume. It is approximately 1100 mL.
4. Residual volume (RV). It is the volume of the air that still remains in the lungs after the most forceful expiration. It is about 1200 mL in a normal adult male, and it can be expelled out of the lungs only after their collapse (e.g. after opening of the chest).

The various lung volumes and their average normal values in young adult mules

Figure 1. Sample Spirogram in a Normal, Healthy Patient



Static Lung Volumes and Capacities

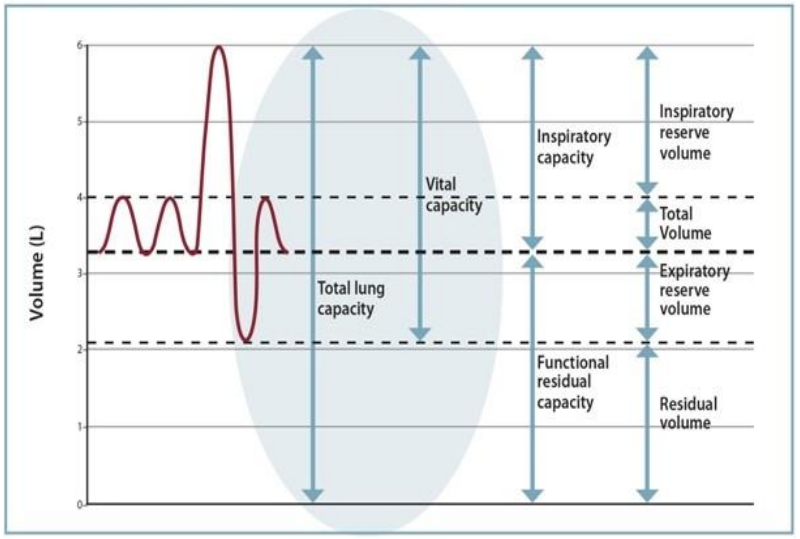
THE LUNG CAPACITIES :

Lung capacities are combination of two or more pulmonary volumes and include :

1. Inspiratory capacity. This is the maximum volume of the air that can be inspired after normal tidal expiration. Therefore, it equals the tidal volume plus inspiratory reserve volume (TV + IRV) and is approximately 3500 mL.
2. Functional residual capacity. It is the volume of the air remaining in the lungs after normal tidal expiration. Therefore, it equals the expiratory reserve volume plus the residual volume (ERV + RV) and is about 2300 mL.

Emphysema??

The various lung volumes and their average normal values in young adult mules



Significance of FRC

- Continuous exchange of gases
- Breath holding is made possible
- Load on respiratory mechanism and right ventricle

Static Lung Volumes and Capacities

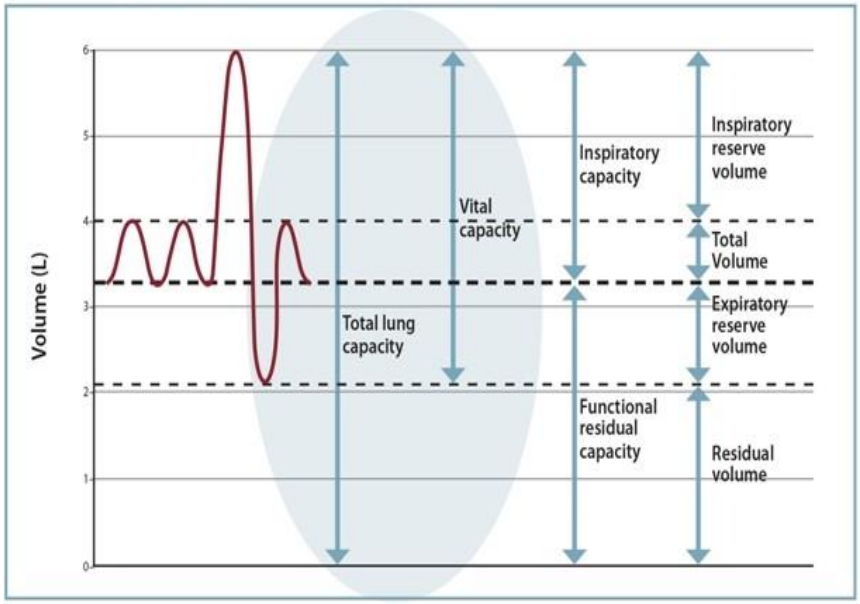
3- Vital capacity (VC). This is the maximum amount of air a person can expel from the lungs after the deepest possible inspiration. Therefore it equals tidal volume plus inspiratory reserve volume plus expiratory reserve volume (TV + IRV + ERV) and is about 4600 ml.

- When expiration is performed as rapidly and as forcibly as possible, the volume is the Forced Vital Capacity (FVC) .
- FVC differs very little from VC in the normal subject, but it is proportionately more reduced when there is airway obstruction with air trapping.

4. Total lung capacity (TLC). It is the volume of air present in the lungs after the maximal inspiration. It equals the vital capacity plus the residual volume (VC + RV) and is about 5800 ml.

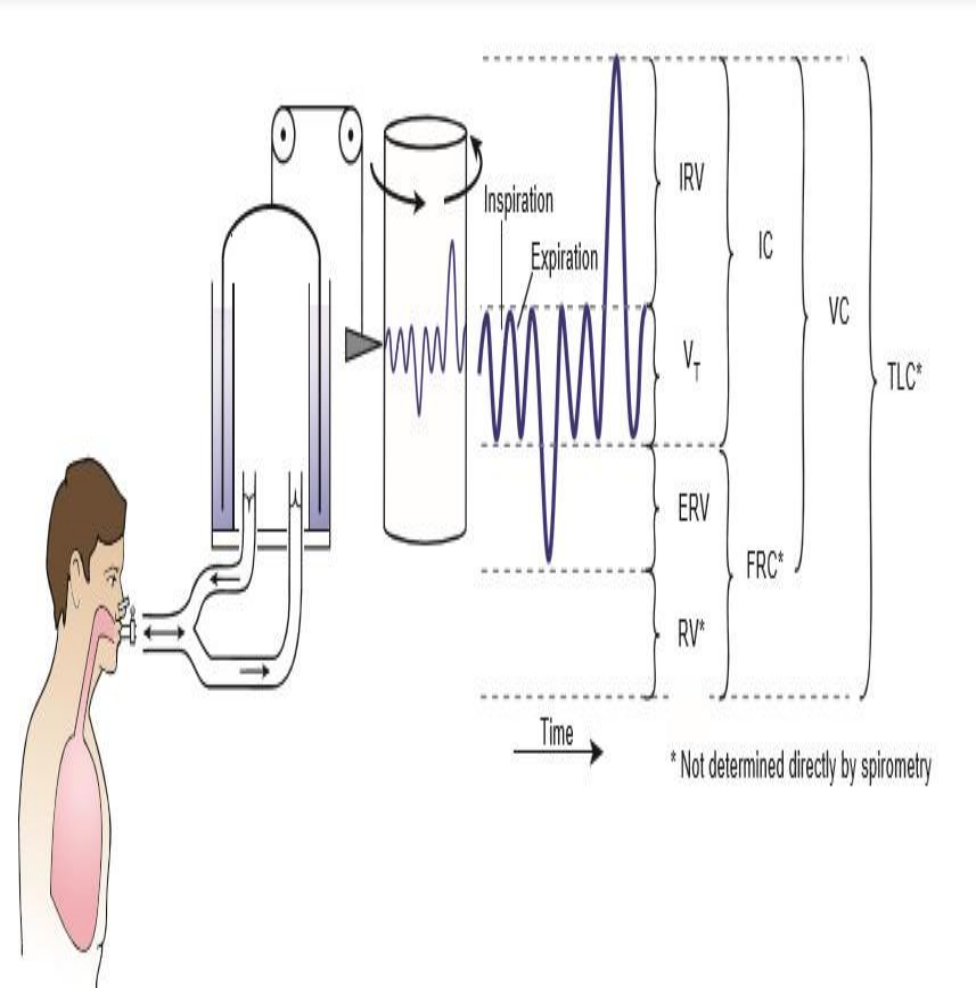
The various lung volumes and their average normal values in young adult mules

Figure 1. Sample Spirogram in a Normal, Healthy Patient



- how does a smoking lead to decreased elasticity?
- by disrupting the elasticity of the lung, for example when emphysema occurs
- it also happens in older people when increase the functional residual capacity due to failing to proper exhalation.
- respiration is a cyclic process, where as perfusion of blood is a continuous process.

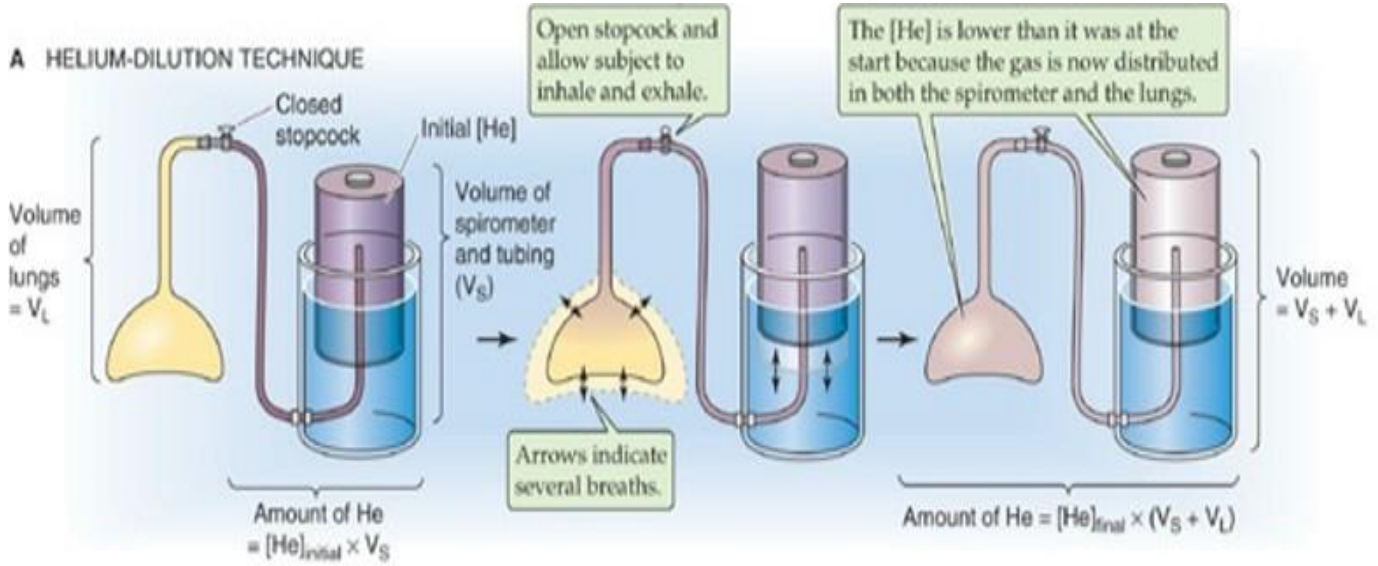
MEASUREMENT OF THE LUNG VOLUMES AND CAPACITIES



Measurement of the residual volume (RV)

Residual lung volume cannot be measured directly by spirometry

Helium dilution technique



$$[He]_{initial} \cdot V_S = [He]_{final} \cdot (V_S + V_L)$$

Solving for lung volume,

$$V_L = V_S \cdot \left(\frac{[He]_{initial}}{[He]_{final}} - 1 \right)$$

Clinical importance of measuring the RV??

Normally, the RV is less than 30 % of the TLC

- some volumes for example residual volume and functional residual capacity need to be measured by helium dilution technique.
- why helium ??
- because it is an inert gas (خامل) that the body doesn't produce it.
- it is also an insoluble gas in the body.

- it is a closed circuit, so helium before equilibrium = helium after equilibrium.

- RV/FRC= unkown, but concentration of helium before is known
- volume of a spirometer is known.
- C1*V1 = C2*V2 (Concentration law)
- The concentration of helium after can be measured

- you must do forced expiration to calculate residual volume and you must do normal expiration to calculate functional residual capacity.

- opening the knob changes it from a close to an open circuit .
- residual volume is normally less than 30 % of the total capacity.
- if it is more than 30 liter that means chronic obstructive/ restrictive lung disease.

MECHANICAL PROPERTIES OF LUNGS AND CHEST WALL

LUNG MECHANICAL PROPERTIES

- **Ventilation occurs as a result of pressure differences induced by changes in lung volume.**
- **Physical properties that affect changes in lung volume:**
  - **Distensibility is the term applied to the ease with which the lungs can be stretched or inflated. It also known as lung compliance.**
  - **Stiffness is defined as resistance to stretch or to inflation.**
  - **Elastic recoil is defined as the ability of a stretched or inflated lung to return to its resting volume.**
    - **The recoil forces in the lungs are generated by the presence of elastin fibers in the lung**
- **Compliance=1/elastance**

- pressure gradient happens by inducing change in the lung volume.

- Lung volume change → pressure gradient change → ventilation occurs.
- physical properties that affect lung volumes:

1) stiffness

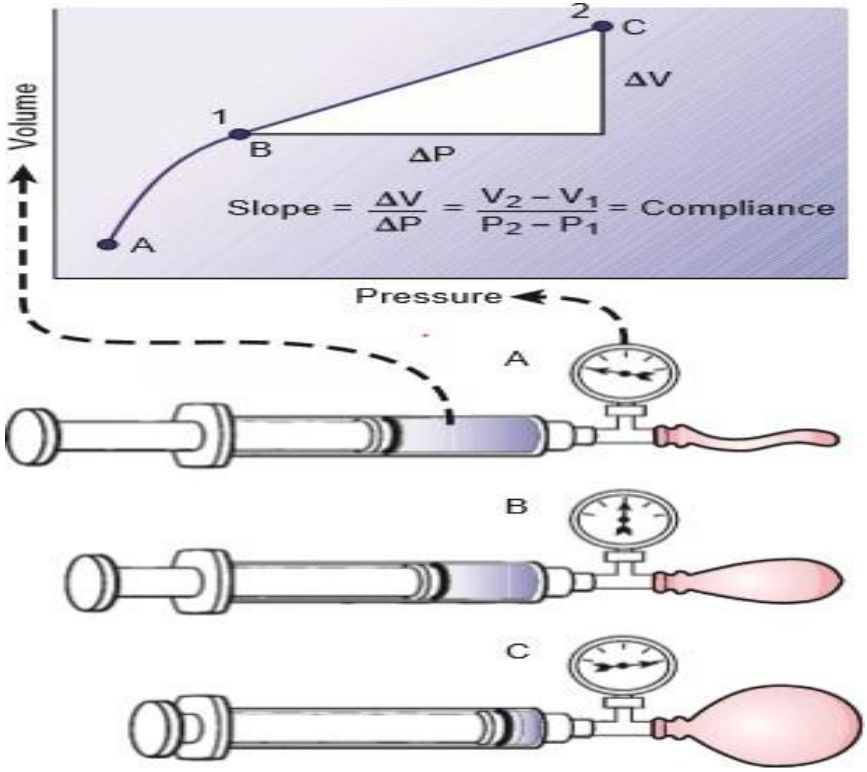
2) distensibity: lung compliance

- normal lungs has an increased compliance.
- elasticity affects compliance because:
- Elasticity = 1/ compliance

Compliance of the Lungs

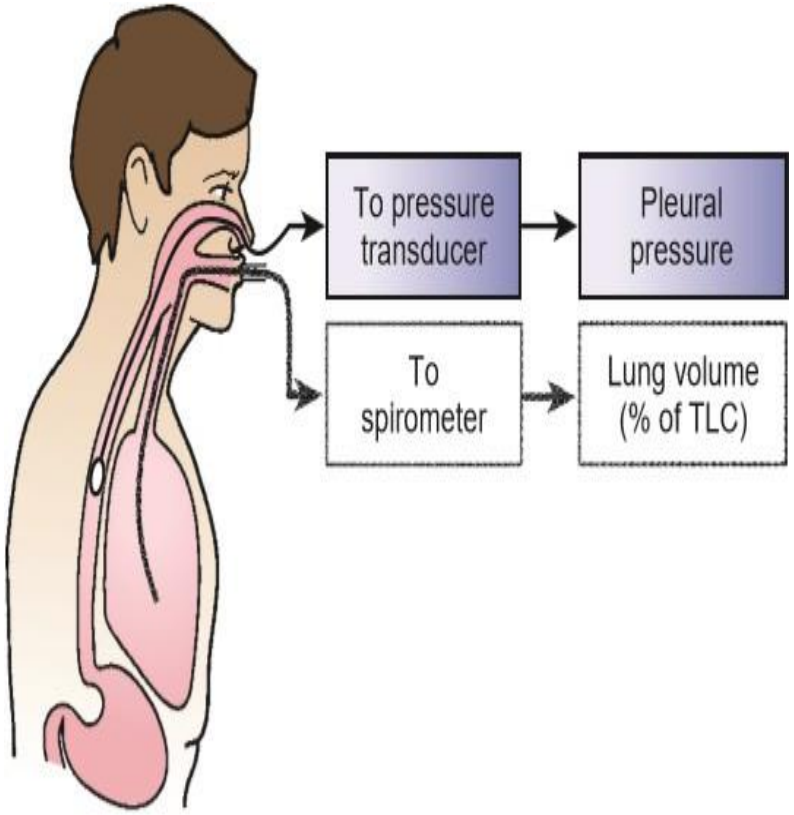
- Lung compliance
  - is an index of the effort required to expand (distend) the lungs to overcome recoil.
  - The greater the lung compliance, the easier to expand the lungs at any given change in pressure.
  - Compliance can be assessed from the pressurevolume curve of the lung.
  - Graphically, lung compliance is the slope of the line between any two points of the pressure-volume loop i. e. Compliance = ΔV/ΔP,

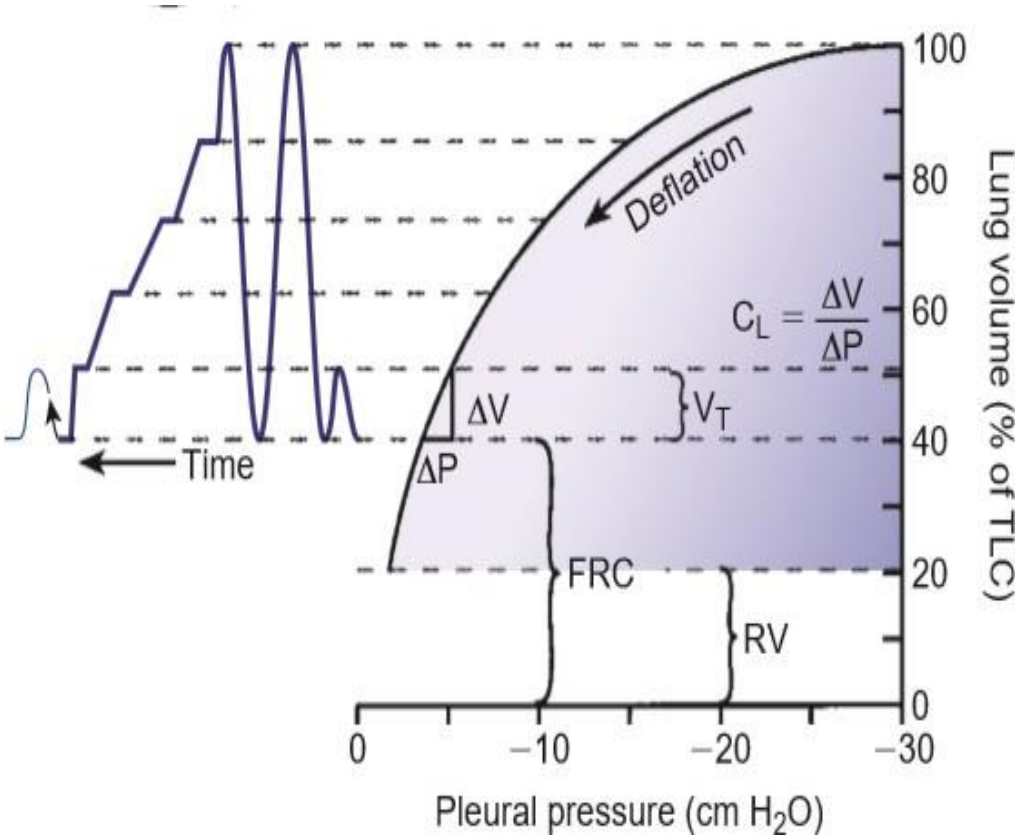
where ΔV is the change in volume and ΔP is the change in pressure



The compliance of the lungs alone (when removed outside the body) is normally about 0.2 liter/cmH2O pressure

Measurement of Lung Compliance



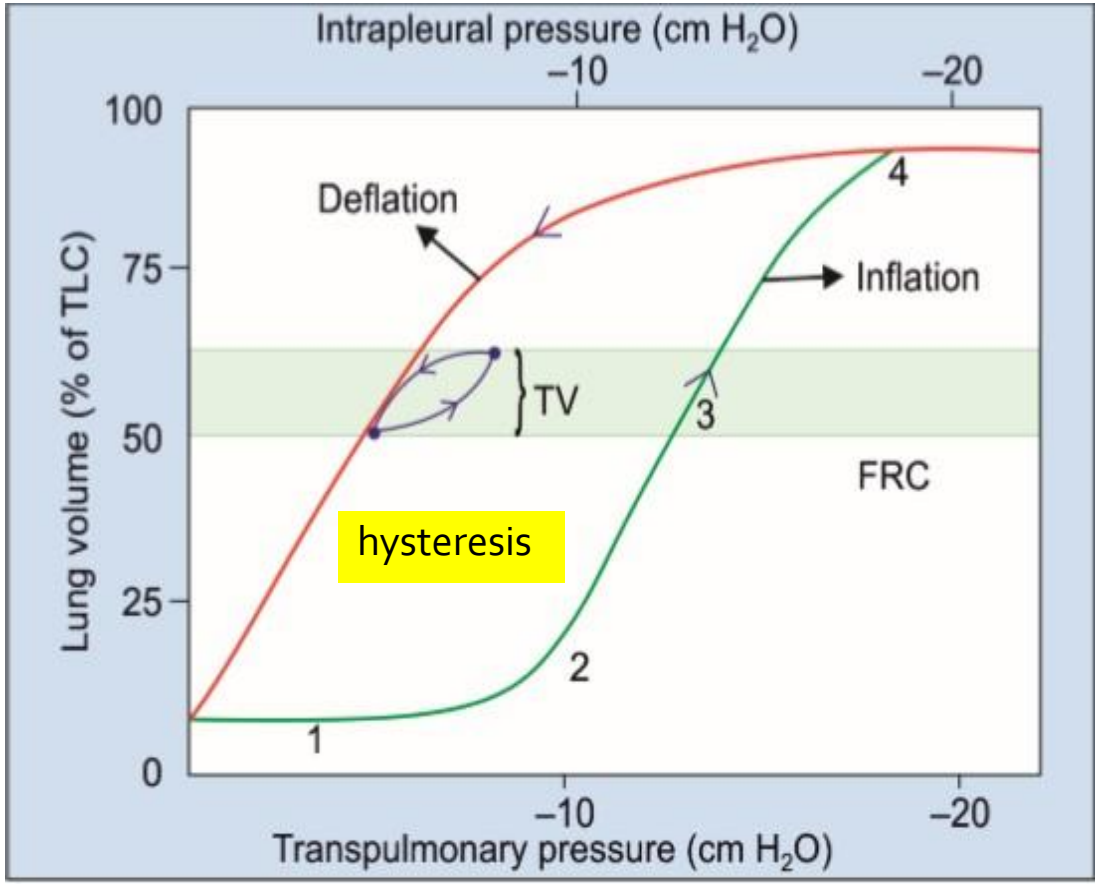


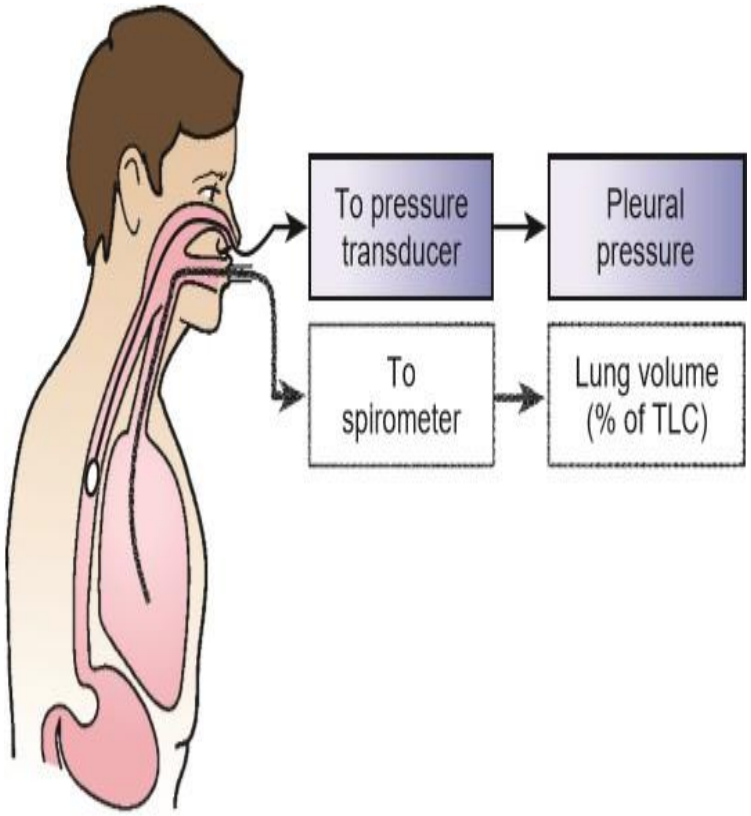
- too much elasticity = stiffness
- When elasticity increase stiffness increase

- when compliance increase inhalation increase and exhalation decrease do to decrease the elasticity.

Measurement of Lung Compliance

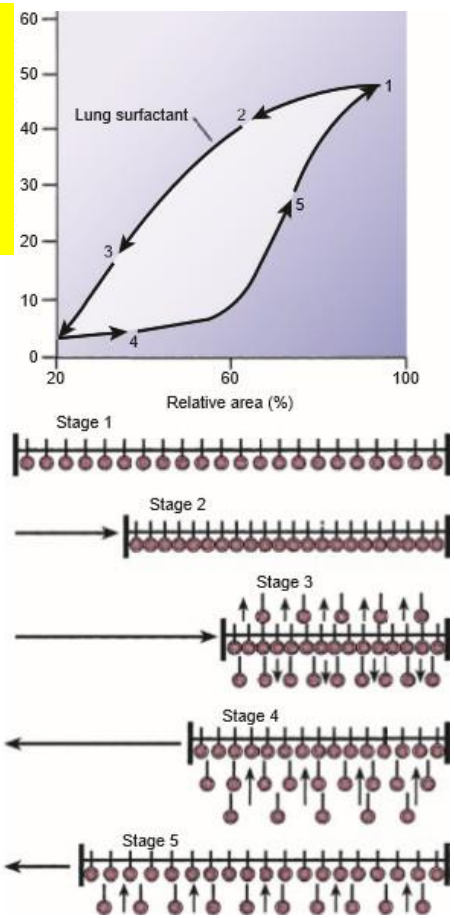
Static Lung Compliance Measurement





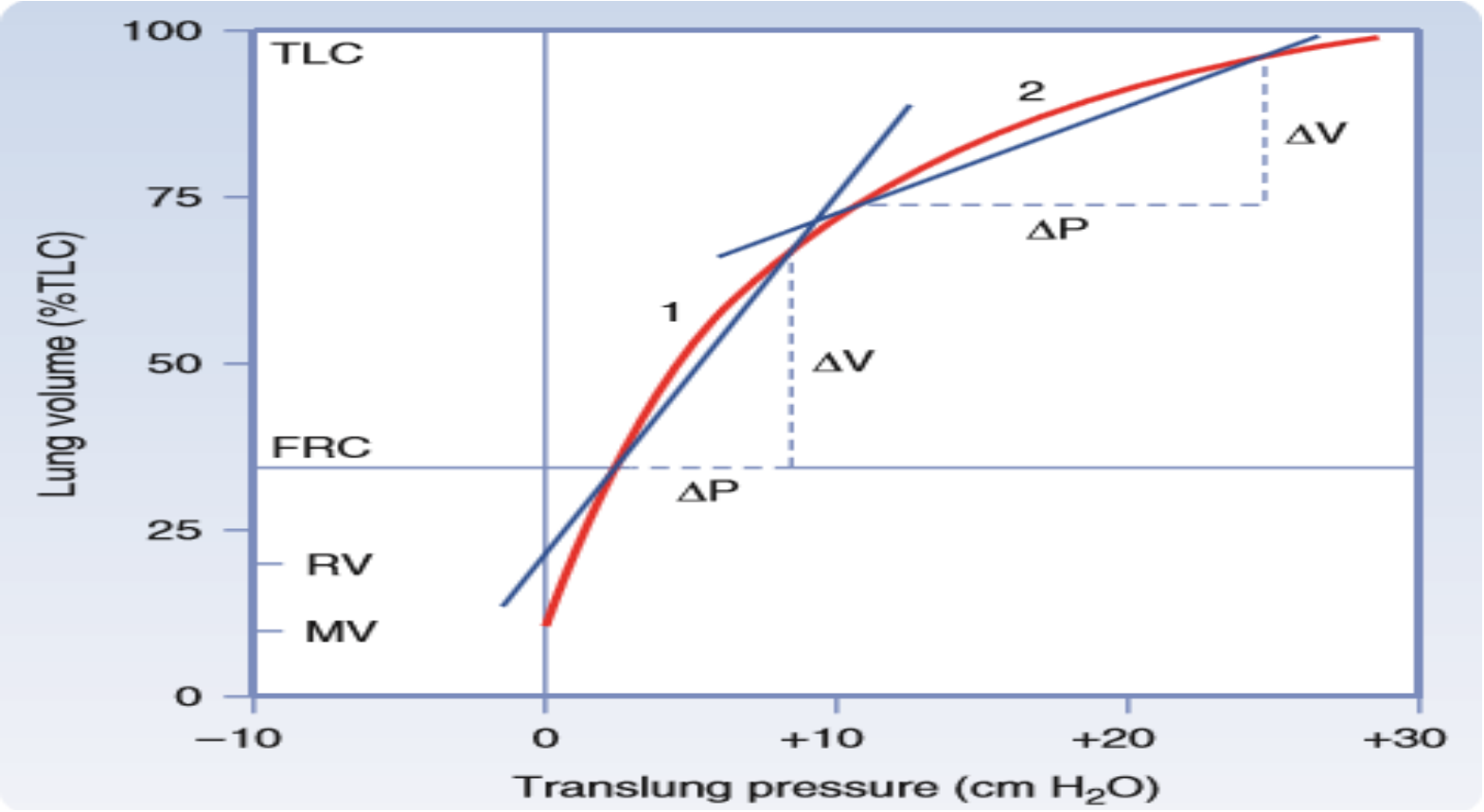
Role of Surfactant in Pulmonary Mechanics

- Turnover of lung surfactant is high because of continual replacement of surfactant during lung expansion.



Atelectasis following surgery??

Factors Affecting Lung Compliance



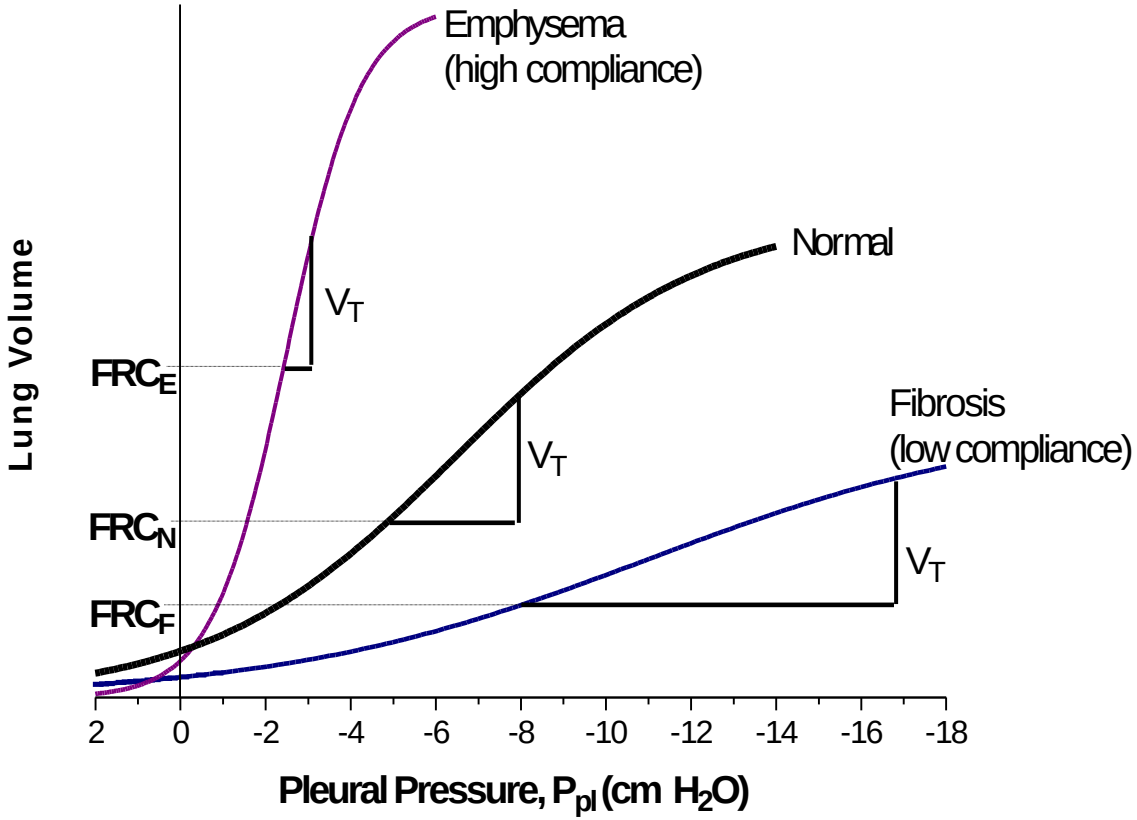
- **Lung volume**
- **Lung size…..specific compliance.**
- **Surface tension inside the alveoli**

Clinical Significance of Lung Compliance

Diseases of lung alter the lung compliance.

- Low lung compliance is seen in restrictive lung diseases like fibrosis.
- High compliance is seen in obstructive lung diseases like emphysema

Pneumothorax??
RDS??



- pressure volume curve:

slope of the curve = the compliance

- Compliance = change in volume / change in pressure

- It is a nonlinear curve meaning lung compliance is not equal at all volumes.

- compliance is low at high lung volumes.

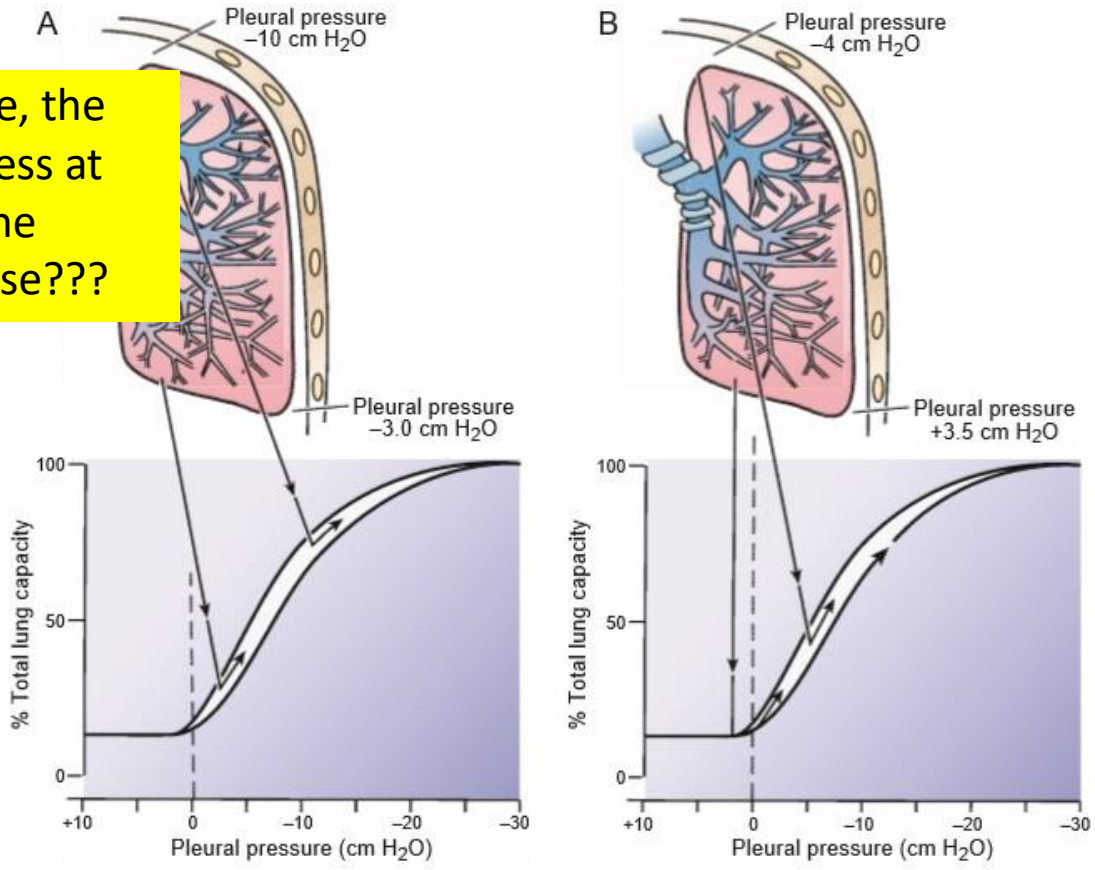
- High compliance equals High change in volume (V) or low change in pressure (P).

- Compliance is highest at the steepest mid area of the curve.

- Change in volume normally = 600 (this is Tidal volume).

Regional Variation of Lung Compliance

- In upright posture, the lung compliance is less at the top portion of the lungs than at the base???



- Assisting human compliance: spirometer is used to measure lung change in volume.

- To measure the plural pressure we measure the esophageal pressure.

- Steps:

1) maximum inspiration (total lung capacity)
2) slow expiration
3) Stop of the Air flow
4) measure the pressure
5) then we measure (RV / FRC)

- inhalation curve starts at FRC / RV, complete opposite until TLC

- compliance of inspiratory curve VS. expiratory curve:
- it's not the same
- even though compliance is an intrinsic factor, this is due to surfactant, and surface tension is working differently at high and low volumes.