Lung Volume and Capacity

MEDEMIA ACADEMY

Normal Breathing cycle

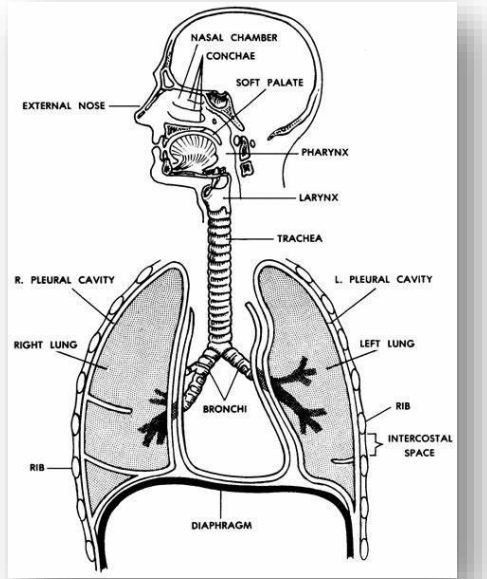
❖**inspiration:**

- Active phase Involves filling the lungs, mainly depending on the diaphragm and intercostal muscles to expand thoracic cavity and maintain negative pressure during quiet breathing (TV) and accessory muscles during deep breaths (IRV).

❖**Expiration:**

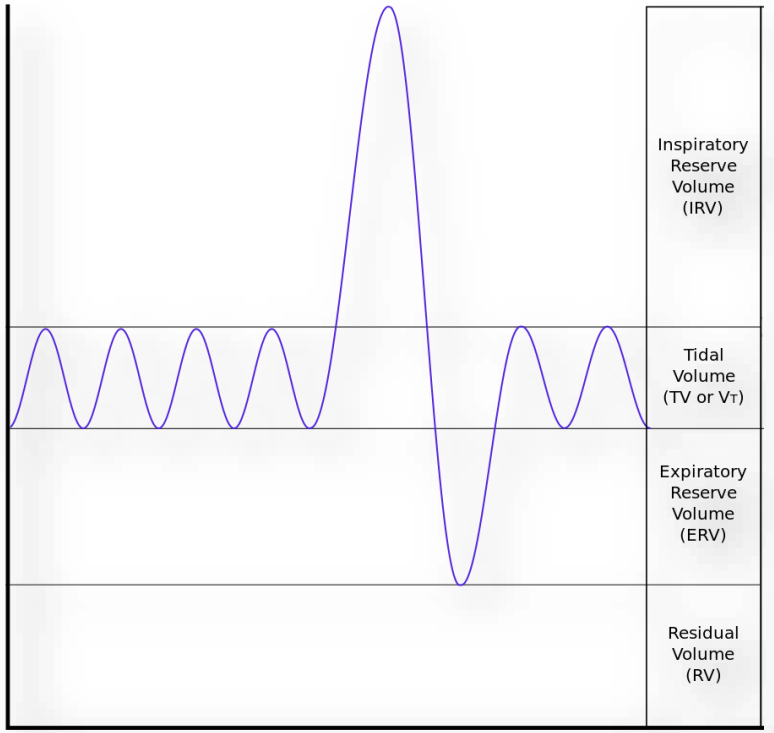
- Passive phase relies on relaxation of muscles (TV), during deep expiration its requires energy by contraction of internal intercostal muscles and abdominal muscles (ERV).

➢Normal rate per minute is 12-16.



Lung Volumes

- **Tidal volume(TV) =** 500 ml
  - Volume of air inspired or expired per each cycle of normal quiet breathing at rest (eupnea).
- **Inspiratory reserve volume(IRV) =** 3000 ml (above TV).
  - Volume of air which can be inspired by maximum forced inspiration (using of accessory muscles) after normal inspiration.
- **Expiratory reserve volume(ERV) =** 1100 ml(above TV).
  - Volume of air that can be expired by maximum expiration (using of accessory muscles)after normal expiration.
- **Residual volume(RV) =** 1200 ml
  - Volume of air remaining in the lung after maximal expiration(can't be expelled expect incase of lung collapse), Can't be tested by spirometry.
  - made up from first air after birth.

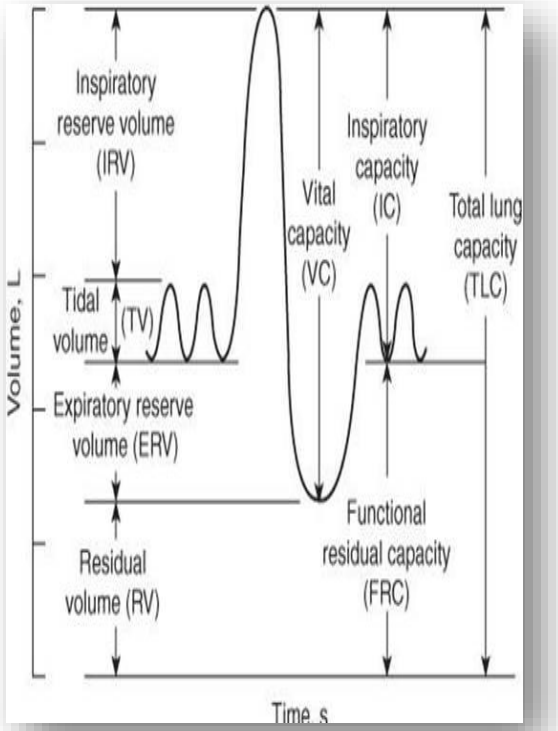


Lung Capacities

❖ **Inspiratory Capacity (IC):**
- Maximum volume of air that can be inspired after a normal expiration.
- IC = TV + IRV = 500ml + 3000ml = 3500ml

❖ **Expiratory Capacity (EC):**
- Maximum volume of air that can be expired after a normal inspiration.
- EC = TV + ERV = 500ml + 1100ml = 1600ml

❖ **Functional Residual Capacity (FRC):**
- Volume of air remaining in the lungs after a normal expiration.
- FRC = ERV + RV = 1100ml + 1200ml = 2300 ml
- Cannot be measured by spirometry.
- Important to provide oxygen to blood in between breathing ,prevent fluctuation of Partial pressure of oxygen.



Lung Capacities Cont.

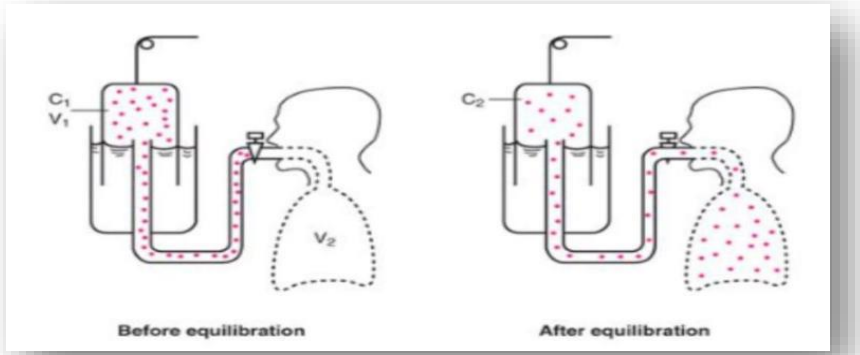
- **Vital Capacity (VC):**
  - Maximum volume of air that can be expired after a maximal inspiration.
  - VC = IRV + TV + ERV = 3000ml + 500 ml + 1100 ml = 4600ml
- **Total Lung Capacity (TLC):**
  - Volume of air in the lungs after a maximal inspiration.
  - TLC = VC (or sum of all 4 values) + RV = 4600 ml + 1200 ml = 5800ml
  - Cannot be measured by spirometry.

Nomenclature

- Eupnea:
  - The process of normal breathing.
- Tachypnea(hyperpnea):
  - Increased rate of breathing.
- Bradypnea:
  - Decreased rate of breathing.
- Apnea:
  - Stopped breathing (holding breath).
- Dyspnea:
  - Awareness of breath (difficulty breathing).

Static pulmonary function tests

1. **Residual volume:**
   - Measured by Helium dilution method, using the dilution principle.
   - C1 x V1 = C2 x V2
   - Helium is used as an inert gas (no reaction), not diffuse to blood from alveolar air
   - We use Helium as indicator because, it is inert gas, not produced or utilized by the body that will remain constant, not escape the alveolar wall “will trapped inside” and not passed to pulmonary capillary).
   - We can also measured FRC by this test (Avoid forced expiration at start).



Importance of Residual volume

1. Provides air in alveoli to oxygenate the blood between breaths(during periods of apnea in order to deliver oxygen to tissue, provided by RV and FRC).
2. Prevents lung collapse and keeps the lung distended (decrease works of breathing).
3. Prevents marked changes in PO2 and PCO2 in the blood with each respiration.
4. Prevents marked changes in inspired air temperature and humidity (RV have same body temperature that will offer condition of the inspired air).

Importance of Residual volume Cont.

5. Ratio of RV / TLC is less than 30%, that's important clinically to diagnose different diseases, As in bronchial asthma and emphysema the ratio increase due to insufficient expiration.

6. **Medico legal importance:**
   - To determine the cause of death of a baby after birth, we examine the lungs, even if the lungs collapse, they will contain at least 150 ml of air(minimal air).
   - If the baby was born alive and has respired, the lungs will float in water due to residual air as in pic A, If the baby was born dead and has not respired, the lungs will sink in water as they contain no residual air as in pic B.

(A)

(B)

Importance of TLC and VC

2. **Total lung capacity (TLC):**
   - Significance:
     - Decrease in pneumothorax, pulmony fibrosis, pulmony congestion and hydrothorax(fluid in thoracic cavity) ,it will be low also in cases of Restrictive lung disease, and any condition affects lung distension.
3. **Vital capacity (VC):**
   - Measured by spirometer.
   - Significance:
     - It indicates the strength of respiratory muscles(especially the expiratory muscles)and lung elasticity.

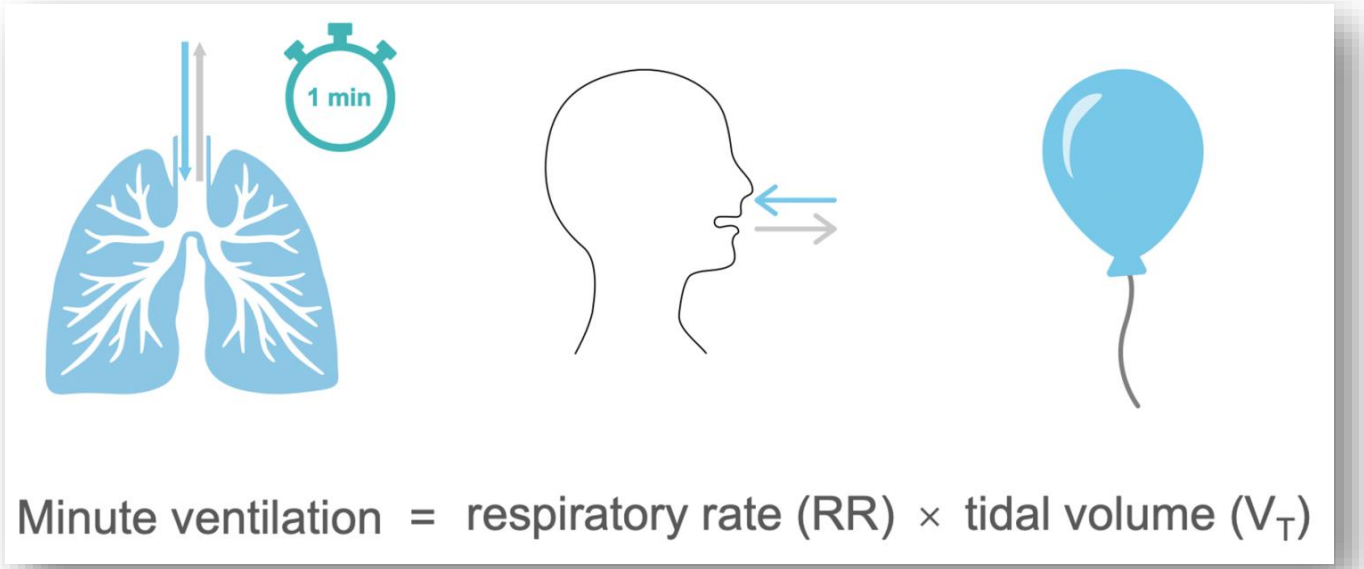
Factors affecting Vital Capacity

	Increase	Decrease
Physiological	Athletes	Females, old age, pregnancy and recumbent position due to return of more blood to the lung (interfere diaphragm movements).
Pathological		**a. Chest wall diseases**: • Paralysis of respiratory muscles &myasthenia gravis. • Fracture ribs or kyphosis(limit expansion of thorax). **b. Lung diseases**: • Decreased compliance (stretchability) as (fibrosis, hydrothorax, pneumothorax). • Decreased elasticity as (**emphysema**). • Obstructive conditions like **bronchial asthma** as resistance to air flow mainly during expiration. **c. Increased blood volume in the lung**: • as in pulmonary congestion by left side heart failure. **d. Presence of intra-abdominal masses**: • as tumour and ascites(free fluid in peritoneum), prevent free descent of diaphragm.

Dynamic pulmonary function tests

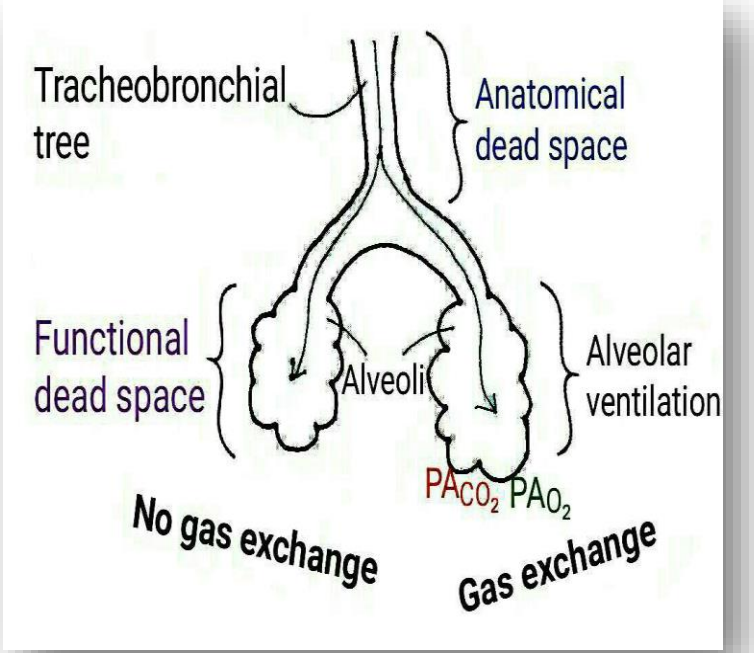
❖ **Respiratory minute volume (RMV) (Minute ventilation):**

- It is the volume of air respired/min, regarded as total pulmonary ventilation.
- At rest = TV x respiratory rate = 0.5 x 12 = 6 L/min (not all value participate in gas exchange that we measure EVV).



Dead space

- It is the Volume of air which does not undergo gas exchange in respiratory system.
- **Types:**
  1. **Anatomical DS**: thick respiratory passages (from nose to terminal bronchioles), named conducting zone.
  2. **Alveolar DS:** non functioning alveoli, these alveoli ventilated but not perfused usually at apex (normally absent "pathological"), as in PE.
- **Physiological DS**: = anatomical + alveolar DS. Normally, DS = anatomical = 150 ml
- N.B.: Inspiration through a tube → increases DS

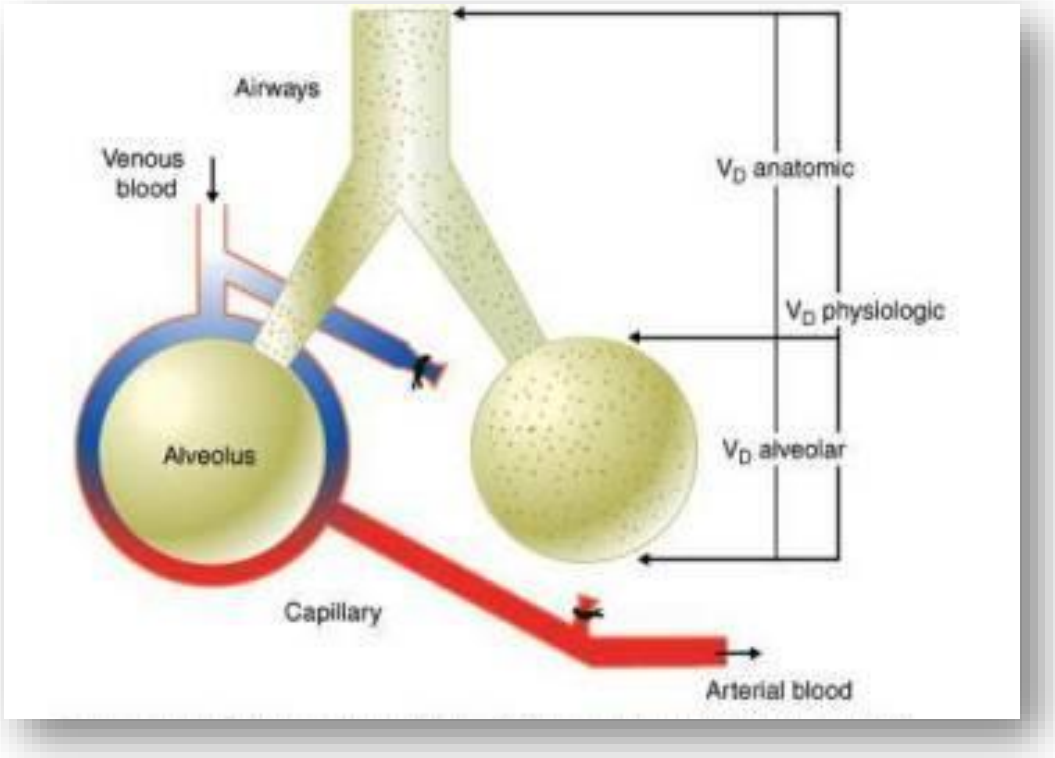


Significance of Dead Space

1. Protective functions, as cough reflex and phonation.
2. Prevents marked changes in PO2 and PCO2 in the blood with each respiration.
3. Prevents marked changes in inspired air temperature and humidity.
4. To make difference between Respiratory minute volume (RMV) & Effective ventilation volume (EVV).

Effective ventilation volume (EVV):

- It is the volume of air that enters in gas exchange/ min.
- Regarded as Alveolar ventilation.
  - At rest=(TV – DS) x respiratory rate = 0.35 x 12 = 4.2 L/min.



Maximum breathing capacity (MBC)

- **Maximum breathing capacity (MBC) or maximum voluntary ventilation:**
  - Maximal volume of air that can be inspired or expired using the deepest and fastest respiratory movements, this is to test the efficiency of lungs and how much air they can handle during extreme conditions, such as heavy exercise or deep breathing.
  - The value differ from person to another according to strength of muscle that usually males have higher values.
  - MBC= 80 to160 L/min in males, 60 to120 L/min in females.
- Measured in 15 seconds then multiplied by 4,rather than per minute because : increase respiration will wash CO2 and results with respiratory alkalosis that drives Ca loss and favoring tetany.

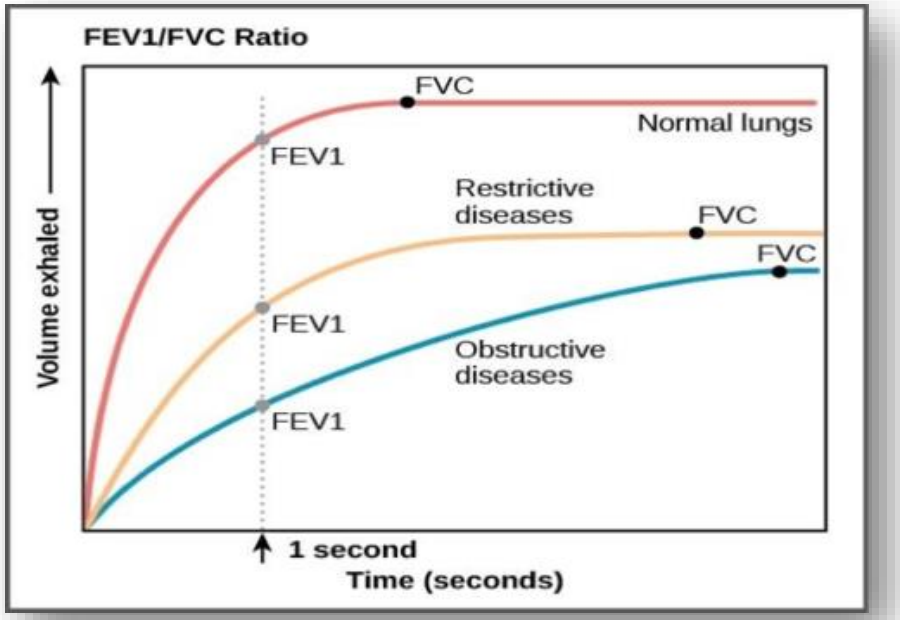
BR and DI

- **Breathing reserve(BR).**
  - The difference between the MBC and RMV.
  - BR = 100 – 6
    = 94 L.
- **Dyspneic index (DI):**
  - The percentage between the breathing reserve and the MBC.
  - Normally DI > 90%
  - If DI < 70% Dyspnea.

Timed Vital Capacity

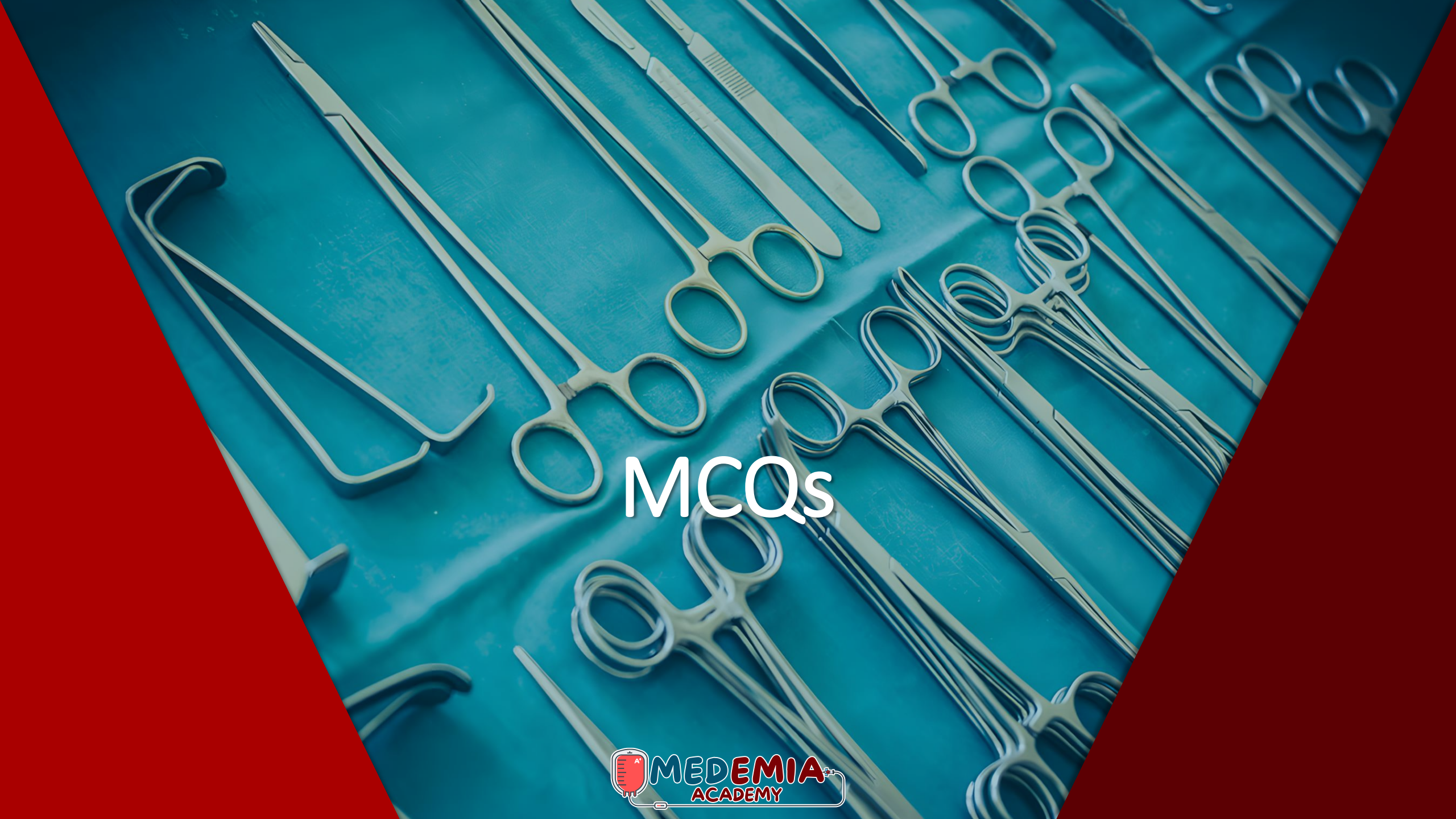
❖**FEV1:**

- The fraction of vital capacity expired maximally and rapidly in the first second.
- FEV1= 83% of VC, and reaches 97% in three seconds and fully in 4-6 seconds
- Help to diagnose airway resistance RLD and OLD especially to differentiate between(Asthma and emphysema) and for prognosis and follow up after managements.



Obstructive Vs Restrictive lung disease

	Obstructive lung disease (OLD)	Restrictive lung disease (RLD)
Example	Asthma, Emphysema	Lung fibrosis, Pneumothorax (interfere with lung expansion)
Vital capacity (VC)	Decreased	Decreased
FEV1	Decreased markedly	Decreased
FEV1/VC Ratio	Reduced (because FEV1 decreases more than VC)	Maybe normal (as both decreased equally)
Total lung capacity (TLC)	Almost normal (due to insufficient expiration)	Reduced
	(it helps if we measure TLC first to know if the patient have OLD or RLD)	
Residual Volume (RV)	Increased (due to air trapping)	Reduced



MCQs

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MCQs

1. **FEV1 refer to ?**
   - a. Volume of air exhaled in one second.
   - b. 3000 ml.
   - c. Normal ratio is FEV1 is 30%.
2. **Volumes and flows in the lung?**
   - a. The volume reaching the blood gas per minute on the gas side and the blood side is different.
   - b. The ventilation rate is approximately 5250ml/min.
   - c. The ratio of ventilation to pulmonary blood flow is more than one.
   - d. The volume of alveolar gas and the volume of blood capillary at any instant
   - in time is the same.
   - e. The ventilation rate is approximately 7500ml/min.

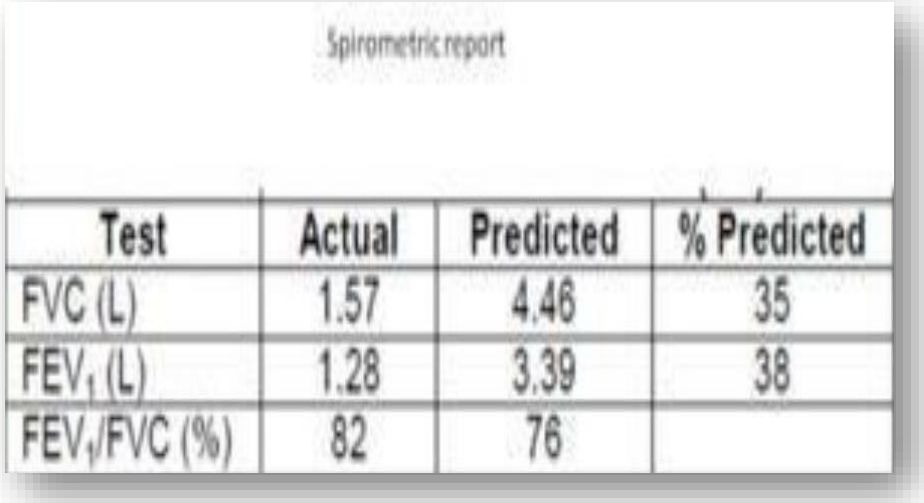
MCQs Cont.

3. **Decreased ratio of FEV to FVC indicates:**
   - a. Obstructive disease.

4. **All true about residual volume except:**
   - a. Measure by Spirometry.

Lab

1. **What is your interpretation about this spirometric report?**
   - a. Restrictive disorder.
   - b. Normal spirometry.
   - c. None of the above.
   - d. Obstructive disorder.
   - e. Post-bronchodilator test should be done to this patient.
2. **Which of the following can be measured by spirometer? (No image)**
   - a. Functional residual volume.
   - b. Residual volume.
   - c. Inspiration capacity.
   - d. Total lung capacity.
   - e. Air in Dead space.

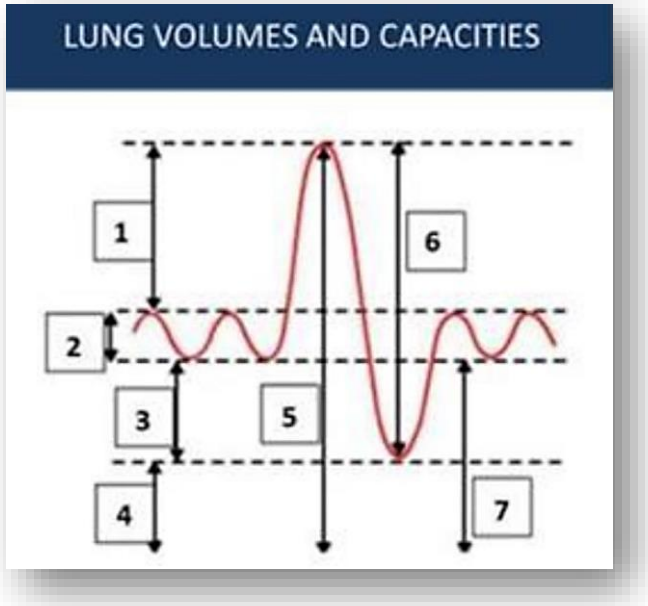


Spirometric report

Test	Actual	Predicted	% Predicted
FVC (L)	1.57	4.46	35
FEV_1 (L)	1.28	3.39	38
FEV_1/FVC (%)	82	76	

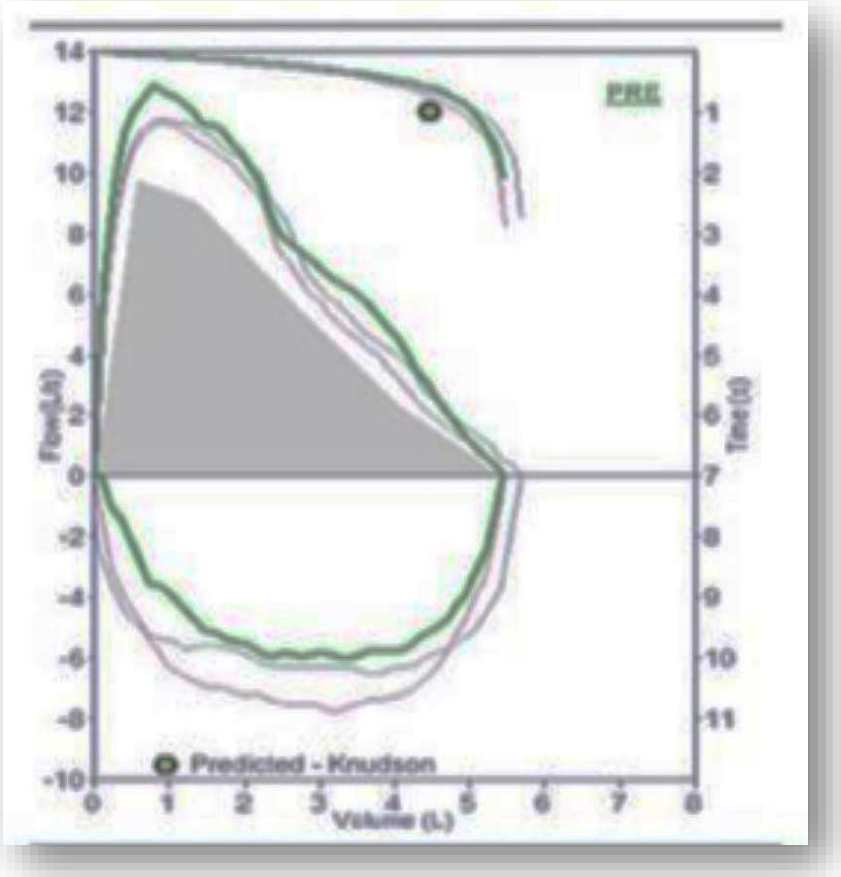
Lab Cont.

3. **Number 6 in the figure referred to which Lung Volume/Capacity?**
   - a. Inspiratory reserve volume.
   - b. Vital capacity.
   - c. Inspiratory capacity.
   - d. Total lung capacity.
   - e. Tidal volume.
4. **Which of the following does the spirometer measure? (No image)**
   - a. Vital capacity.



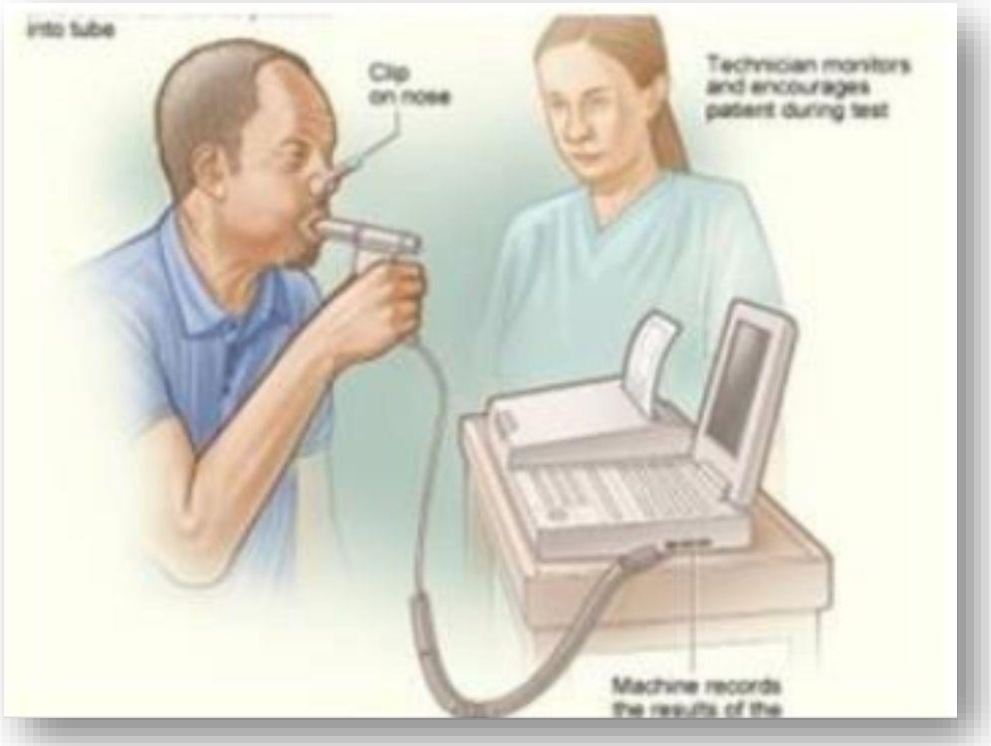
Lab Cont.

5. **One of the following about this figure is INCORRECT?**
   - a. Inspiratory part of the loop is represented below the x-axis (the negative deflection).
   - b. May reveal a characteristic pattern suggestive of restrictive or obstructive pulmonary disorder.
   - c. Normal curve is symmetric and convex inspiratory limb, with linear expiratory limb.
   - d. Expiratory time should be at least 4 seconds.
   - e. Flow-volume loops are produced by asking the patient to breathe out then in as forcefully as possible.



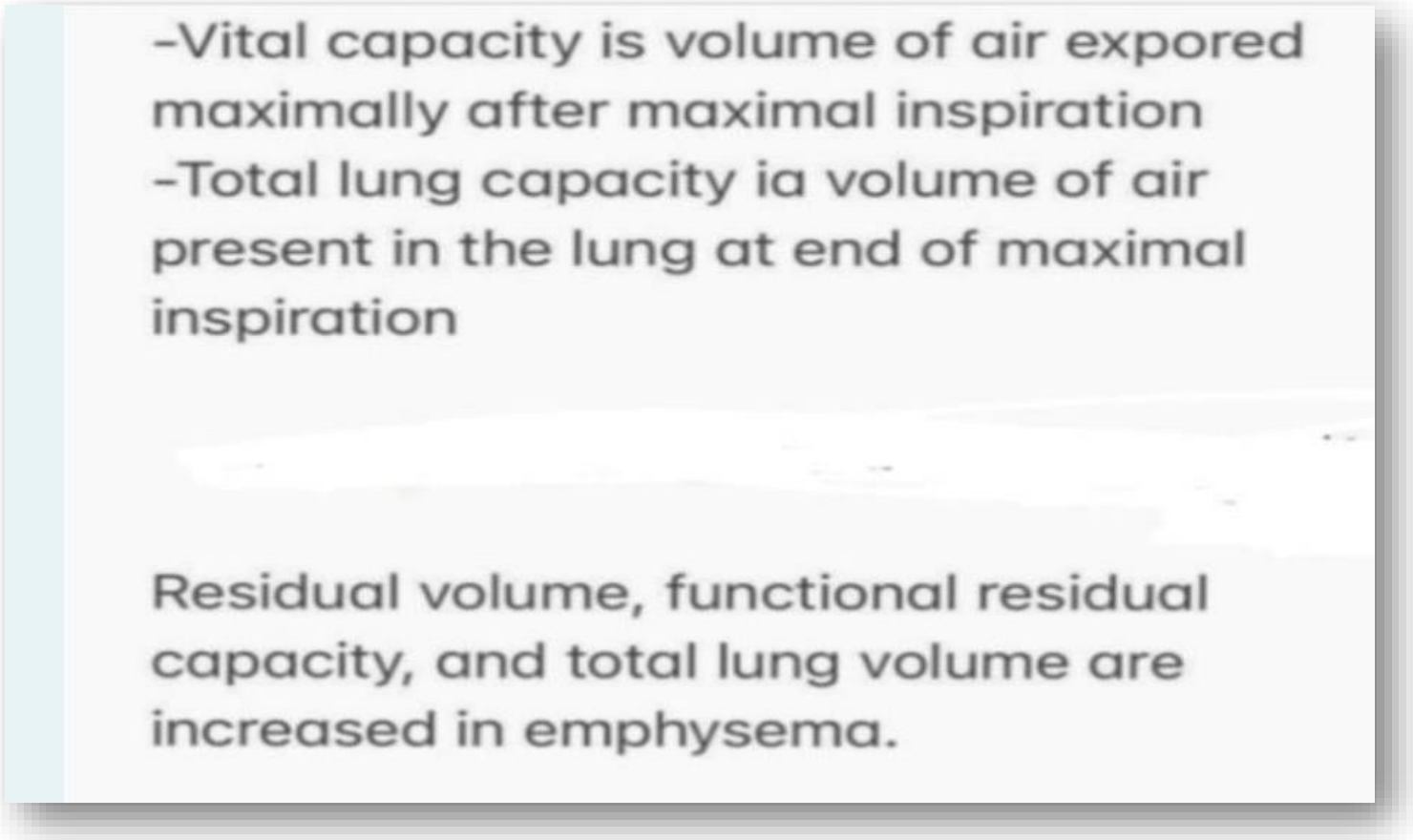
Lab Cont.

6. **One of the following lung volumes/capacities can NOT be measured by this device?**
   - a. Expiratory reserve volume.
   - b. Tidal volume.
   - c. Total lung capacity.
   - d. Inspiratory capacity.
   - e. Vital capacity.



Lab Cont.

7. Physiological labs important Points:



Answer MCQs and labs

❖MCQs Answer:

1. A
2. E
3. A
4. A

❖Labs Answer:

1. A
2. C
3. D
4. A
5. D
6. C
7. Note.