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Lung Capacities

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Introduction: Lung capacities are the union of two of more lung volumes. Lung capacities are classified into 4 categories such as Inspiratory Capacity (IC), Vital capacity (VC), Functional residual Capacity (FRC) and Total lung capacity (TLC) (Fig. 1).

Inspiratory capacity (IC): Inspiratory capacity (IC) is the maximum volume of air that is inspired after normal expiration (end expiratory Position). It includes tidal volume and inspiratory reserve volume.

IC = TV + IRV

= 500 + 3300 = 3800 mL

Vital capacity (VC): Vital capacity (VC) is the maximum volume of air that Can be expelled out forcefully after a deep (maximal) Inspiration. VC includes inspiratory reserve volume, Tidal volume and expiratory reserve volume.

VC = IRV + TV + ERV

= 3300 + 500 + 1000 = 4800 mL

Vital capacity is significant physiologically and its determination is useful in clinical diagnosis as explained.

Functional residual capacity (FRC): Functional residual capacity (FRC) is the volume of air remaining in lungs after normal expiration (after normal tidal expiration). Functional residual capacity includes expiratory reserve volume and residual volume.

FRC = ERV + RV

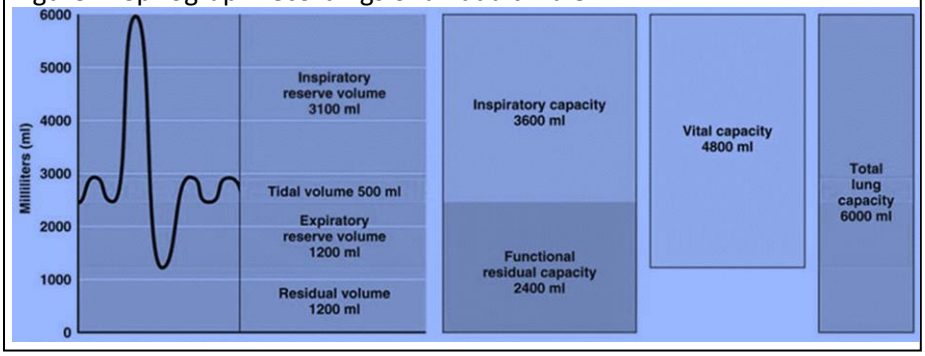
= 1000 + 1200 = 2200 mL

Total lung capacity (TLC): Total lung capacity (TLC) is the volume of air present in lungs after a deep (maximal) inspiration. It includes all the volumes.

TLC = IRV + TV + ERV + RV

= 3300 + 500 + 1000 + 1200 = 6,000 mL.

Figure 1: Spirograph recordings of an adult male



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Measurement of lung capacities: Lung capacities are measured particularly by Spirometer. The simple and uncomplicated equipment utilised for this purpose is termed as spirometer. The modified Spirometer is also termed as respirometer. Nowadays the lung capacities are measured by plethysmograph as well.

Spirometer: Spirometer is made up of metal and it contains two chambers namely outer chamber and inner chamber. Outer chamber is called the water chamber because it is filled with water. A floating drum is immersed in the water in an inverted position. Drum is counter balanced by a weight. Weight is attached to the top of the inverted drum by means of string or chain. A pen with ink is attached to the counter weight. Pen is made to write on a calibrated paper, which is fixed to a recording device. Inner chamber is inverted and has a small hole at the top. A long metal tube passes through the inner chamber from the bottom towards the top. Upper end of this tube reaches the top portion of the inner chamber. Then the tube passes through a hole at the top of inner chamber and penetrates into outer water chamber above the level of water. A rubber tube is connected to the outer end of the metal tube. At the other end of this rubber tube, a mouthpiece is attached. Subject respires through this mouthpiece by closing the nose with a nose clip. When the subject breathes with spirometer, during expiration, drum moves up and the counter weight comes down. Reverse of this occurs when the subject breathes the air from the spirometer, i.e. during inspiration. Upward and downward movements of the counter weight are recorded in the form of a graph. Upward deflection of the curve in the graph shows inspiration and the downward deflection denotes expiration. Spirometer is used only for a single breath. Repeated cycles of respiration cannot be recorded by using this instrument because carbon dioxide accumulates in the spirometer and oxygen or fresh air cannot be provided to the subject.

Figure 2: Male and female respiratory capacities

	Male	Female	Formula
Total lung capacity (TLC)	6000 ml	4200 ml	Maximum amount of air contained in lungs after a maximum inspiratory effort: TLC = TV + IRV + ERV + RV
Vital capacity (VC)	4800 ml	3100 ml	Maximum amount of air that can be expired after a maximum inspiratory effort: VC = TV + IRV + ERV (should be 80% TLC)
Inspiratory capacity (IC)	3600 ml	2400 ml	Maximum amount of air that can be inspired after a normal expiration: IC = TV + IRV
Functional residual capacity (FRC)	2400 ml	1800 ml	Volume of air remaining in the lungs after a normal tidal volume expiration: FRC = ERV + RV

Spirometer: The modified spirometer is termed as respirometer. Is has an option for removal of carbon dioxide as well as supply of oxygen. The removal of carbon dioxide takes place by placing soda lime inside the equipment. Oxygen is provided to the equipment from the oxygen cylinder with the help of a suitable valve system. The oxygen is accumulated in the inverted drum above water level and the subject can breathe in and out with the equipment for about 6 minutes and the recording can be performed on a continuous basis.

Spirogram: Spirogram is the graphical record of lung volumes and capacities using spirometer. Upward deflection of the Spirogram denotes inspiration and the downward curve Indicates expiration. In order to determine the lung capacities, following four levels are to be noted in spirogram

1. Normal end expiratory level.
2. Normal end inspiratory level.
3. Maximum expiratory level.
4. Maximum inspiratory level.

Measurement of functional residual capacity (FRC): Functional residual capacity cannot be measured by spirometer and can be determined by three methods: Helium dilution technique (HDM), Nitrogen washout method (NWM), Plethysmograph.

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Helium dilution technique: Procedure to Measure Functional Residual Capacity: Respirometer is filled with air containing a known quantity of helium. Initially, the subject breathes normally. Then, after the end of expiration, subject breathe from spirometer. Helium from respirometer enters the lungs and starts mixing with air in lungs. After few minutes of breathing, concentration of helium in the spirometer becomes equal to concentration of helium in the lungs of subject. It is called the Equilibration of helium. After equilibration of helium between respirometer and lungs, concentration of Helium in respirometer is determined.

Functional residual capacity is calculated by the Formula:

FRC = V (C1 – C2) / C2

Where,

V = Initial volume of air in the spirometer.

C1 = Initial concentration of helium in the Respirometer

C2 = Final concentration of helium in the

Spirometer

Measured Values: For example, the following data of a subject are obtained from the experiment:

1. Initial volume of air in Respirometer = 5 L (5,000 mL)

2. Initial concentration of helium in Respirometer = 15%

3. Final concentration of helium in Respirometer = 10%.

Results:

From the above data, the functional residual capacity of the subject is calculated in the following way:

$$FRC = V(C1 - C2)/C2$$

FRC = 5000(15/100 – 10/100)/10/100

= 5000(5/100) /10/100

= 5000 × 5 /10

= 2500 ml

Thus, the functional residual capacity in this subject is 2,500 ml.

Methods to Measure Residual Volume: To determine functional residual capacity, the subject start breathing with spirometer after the end of Normal expiration. To measure residual volume, the subject should start breathing from the respirometer after forced expiration.

Nitrogen washout method: Normally, the concentration of nitrogen in air is 80%. So, if total quantity of nitrogen in the lungs is measured, the volume of air present in lungs can be calculated.

Methods to measure Functional Residual Capacity (FRC): Subject is asked to breathe normally. At the end of normal Expiration, the subject inspires pure oxygen through a Valve and expires into a Douglas bag. This procedure is repeated for 6 to 7 minutes, until the nitrogen in lungs is displaced by oxygen.

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Nitrogen comes to the Douglas Bag. Afterwards, following factors are measured to calculate functional residual capacity.

The following factors are calculated to determine FRC.

1. Volume of air collected in Douglas bag

2. Concentration of nitrogen in Douglas bag.

By using the data, the functional residual capacity is calculated by using the formula:

FRC = C1 × V /C2

Where,

V = Volume of air collected

C1 = Concentration of nitrogen in the collected air

C2 = Normal concentration of nitrogen in the air.

Measured values: For example, the following data are obtained from the experiment with a subject:

i. Volume of air collected = 40 L (40,000 mL)

ii. Concentration of nitrogen in the collected air = 5%

iii. Normal concentration of nitrogen in air = 80%

Calculation: From the above data, the functional residual capacity of the subject is calculated in the following way:

FRC = C1 × V /C2

= (5/100 × 40000)/80/100

= (5×40000)/ 80

= 2500 mL

Thus, functional residual capacity in this subject is 2500 mL..

Methods to measure Residual Volume: To measure the functional residual capacity (Fig. 1-2), the subject starts inhaling pure oxygen after the end of normal expiration and to determine the residual volume, the subject starts breathing pure oxygen after forceful expiration.

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