Slide 1

Respiratory ventilation

Learning objectives

- **By the end of the lecture you should be able to: -**

1-Define the various lung volumes and capacities and provide typical values for each.

2-Define ventilation rate, their typical values, and their measurement.

3- Describe FEV_1 and its role in differentiating obstructive and restrictive lung diseases.

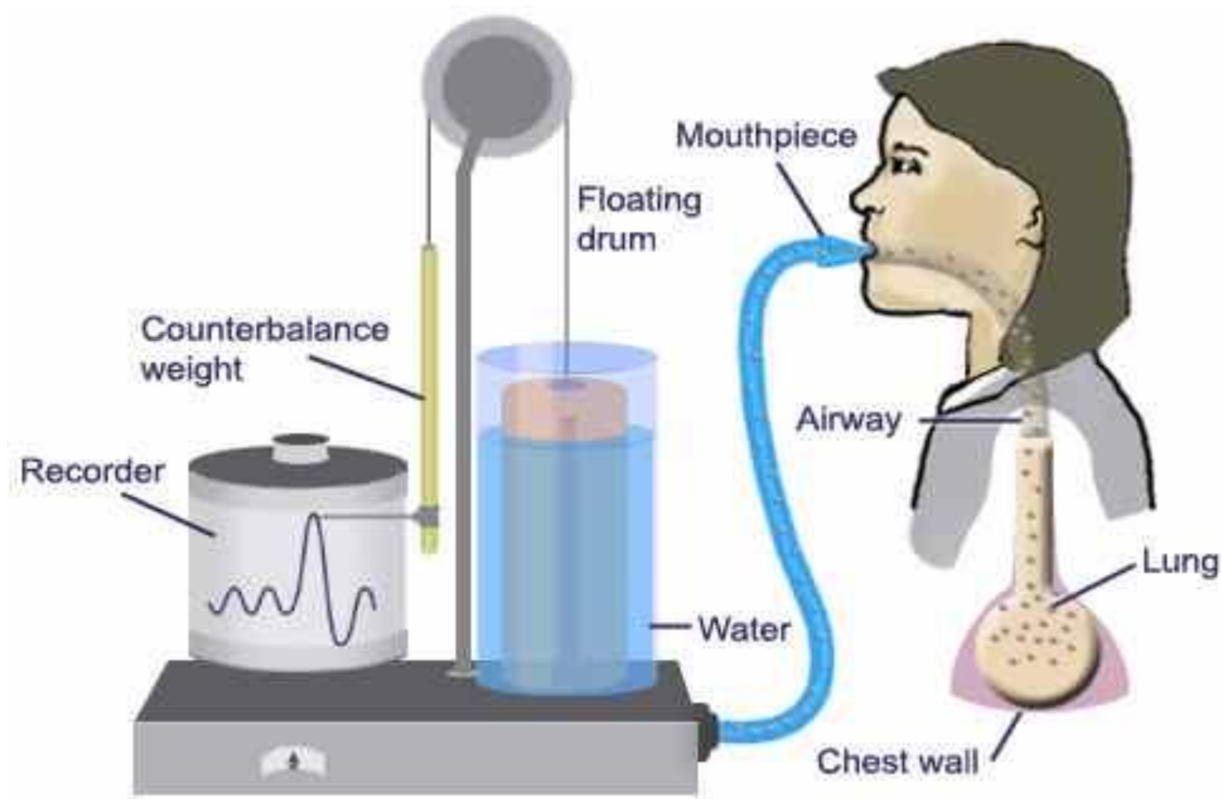
4- Describe the types of dead space. State a volume for the anatomical dead space.

5- Define the term minute ventilation and state a typical value.

6- Distinguish minute ventilation from alveolar ventilation.

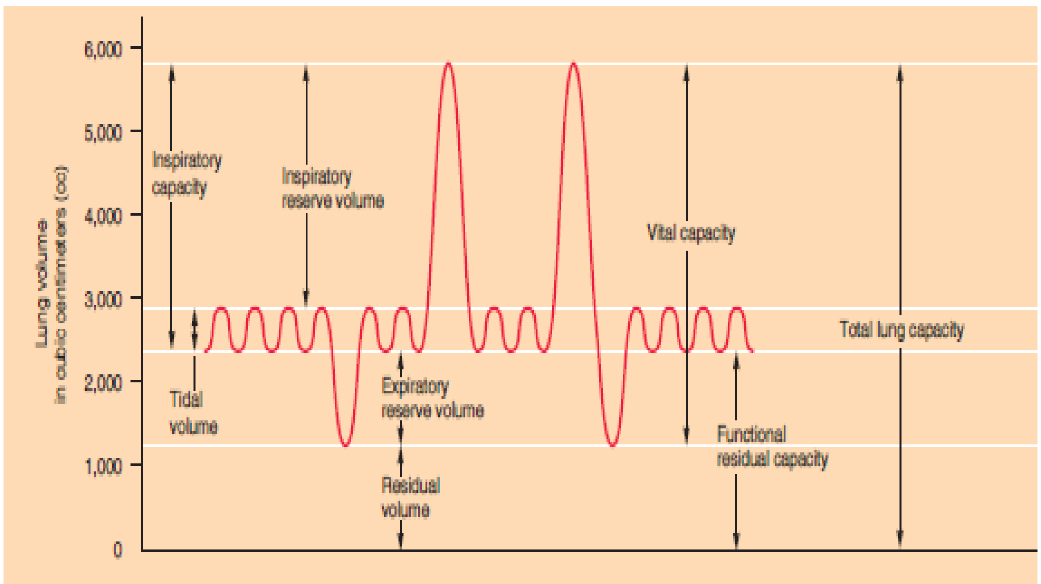
Slide 3

Spirometry



Slide 4

Spiromgram



•Recording the volume movement of air into and out of the lungs, a method called *spirometry*.
•For ease in describing the events of pulmonary ventilation, the air in the lungs has been subdivided in this diagram into four *volumes* and four *capacities*,

Lung volumes and capacities

4 lung volumes:

Tidal volume (TV): Is the volume of air inspired or

expired with each normal breath (~500 ml)

Inspiratory reserve (IRV): Is the extra volume of air that can be inspired over and above the normal tidal volume when the person inspires with full force(~3000 ml)

Expiratory reserve (ERV): Is the maximum extra volume of air that can be expired by forceful expiration after the end of a normal tidal expiration (~1100 ml).

Residual volume (RV): Is the volume of air remaining in the lungs after the most forceful expiration (~1200ml).

Slide 6

Pulmonary capacities

- Two or more lung volumes are described as pulmonary capacity

1- Inspiratory capacity (IC):

Is the amount of air a person can breathe in, beginning at the normal expiratory level and distending the lungs to the maximum amount.

IC= TV+ IRV= 500+ 3000= 3500 ml

2-The functional residual capacity (FRC)

Is the amount of air that remains in the lungs after normal tidal expiration. Acts as a buffer against extreme changes in alveolar gas levels with each breath.

FRC= ERV+ RV= 1100+ 1200= 2300 ml

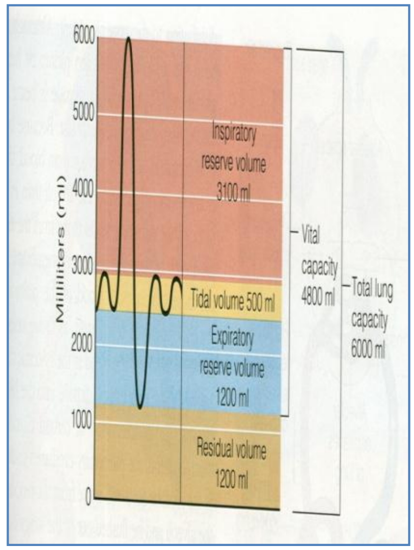
Slide 7

Cont… lung capacities

3-The vital capacity (VC):

The maximum amount of air a person can expel from the lungs after first filling the lungs to their maximum extent and then recording expiring to the maximum extent.

= TV+IRV+ERV =
500+3000+1100 =4600 ml



Cont.. Lung Capacities

4-The total lung capacity (TLC): *is the maximum volume to* which the lungs can be expanded with the greatest possible effort

= TV+IRV+ERV+RV = 500+3000+1100+ 1200= 5800ml.

- ***All lung volumes and capacities*** are 20-25% less in women than men , they are greater in large athletic people than in small asthenic people.

Slide 9

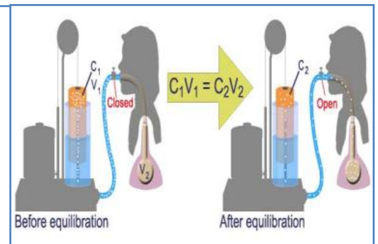
****Determination of the FRC, RV, TLC**

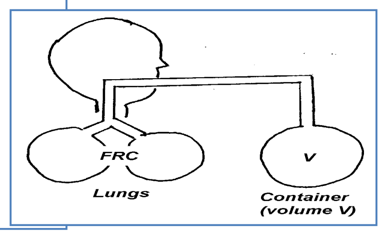
- ***Closed circuit Helium Dilution Method***

$$C1xV1 = C2xV2$$

C1: concentration of Hi in spirometry
V1: volume of air in the spirometry.
C2: Final concentration of helium
V2 :Volume of spirometry+ FRC

$$FRC = \left(\frac{Ci\ He\ (C1)}{Cf\ He\ (C2)} - 1 \right) Vi\ Spi\ (V1)$$





Determination of Functional Residual Capacity, Residual Volume, and Total Lung Capacity—Helium Dilution Method

The functional residual capacity (FRC), which is the volume of air that remains in the lungs at the end of each normal expiration, is important to lung function. Because its value changes markedly in some types of pulmonary disease, it is often desirable to measure this capacity. The spirometer cannot be used in a direct way to measure the functional residual capacity because the air in the residual volume of the lungs cannot be expired into the spirometer, and this volume constitutes about one half of the functional residual capacity. To measure functional residual capacity, the spirometer must be used in an indirect manner, usually by means of a helium dilution method, as follows.

A spirometer of known volume is filled with air mixed with helium at a known concentration. Before breathing from the spirometer, the person expires normally. At the end of this expiration, the remaining volume in the lungs is equal to the functional residual capacity. At this point, the subject immediately begins to breathe from the spirometer, and the gases of the spirometer mix with the gases of the lungs. As a result, the helium becomes diluted by the functional residual capacity gases

Once the FRC has been determined, the residual volume (RV) can be determined by subtracting expiratory reserve volume (ERV), as measured by normal spirometry, from the FRC. Also, the total lung capacity (TLC) can be determined by adding the inspiratory capacity (IC) to the FRC. That is,

Slide 10

Forced Vital Capacity (FVC) and FEV1

(Timed vital capacity)

- *The person is asked to inspire as deeply as possible and then to breath out as hard and as fast as he can.* The expiration is continued until he expired all the air out and thus forced vital capacity is obtained. During this process the volume of air expired in the first second is collected and is known as **FEV1.**

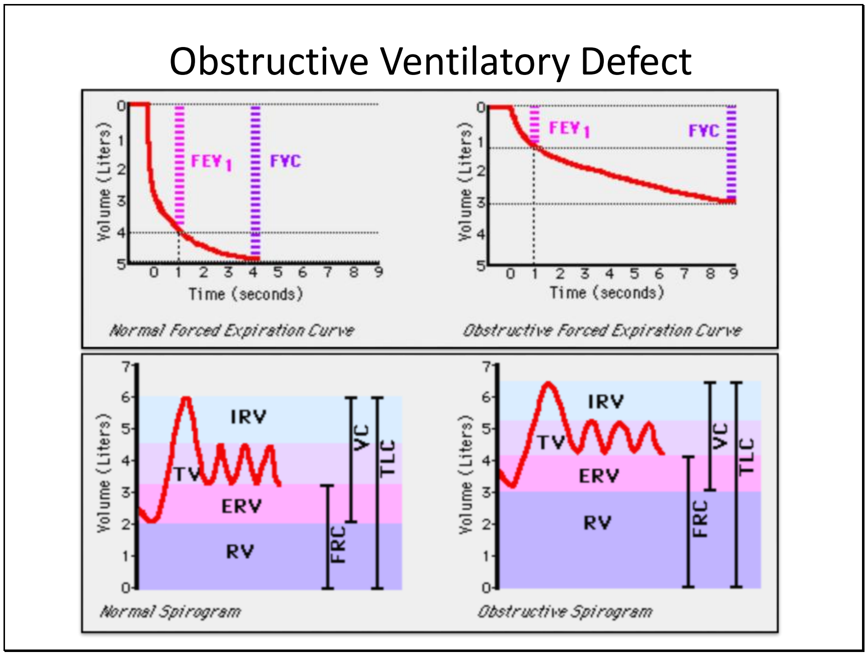
Slide 11

FEV1/FVC ratio

Normally it is about 80%.

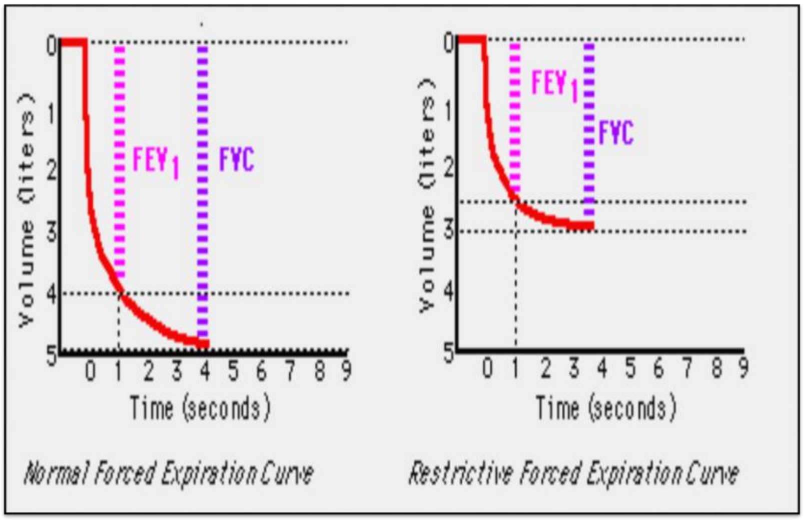
- This ratio differentiate between obstructive and restrictive lung diseases
- Is normal in restrictive lung diseases (e.g interstitial pulmonary fibrosis)
- It decreases in obstructive (bronchial asthma, emphysema)

Slide 12


Obstructive Ventilatory Defect
Volume (Liters)
Time (seconds)
FEV1
FVC
Normal Forced Expiration Curve
Obstructive Forced Expiration Curve
IRV
TV
ERV
RV
FRC
VC
TLC
Normal Spirogram
Obstructive Spirogram

Slide 13

Restrictive Ventilatory Defect



Slide 14

Minute respiratory volume

- ***MRV = Respiratory rate x Tidal volume***

    = RR X TV

    = 12 X 500 = 6L/min.

it could rise to 200 L/min or more than 30 times normal if RR = 40 TV = 4600 ml in young adults man

Minute Respiratory Volume Equals Respiratory Rate Times Tidal Volume
The *minute respiratory volume* is the total amount of new air moved into the respiratory passages each minute; this is equal to the *tidal volume* times the *respiratory rate per minute*. The normal tidal volume is about 500 milliliters, and the normal respiratory rate is about 12 breaths per minute. Therefore, the *minute respiratory volume averages about 6 L/min*. A person can live for a short period with a minute respiratory volume as low as 1.5 L/min and a respiratory rate of only 2 to 4 breaths per minute.

Slide 15

Dead space and its effect on alveolar ventilation

- The volume of air present in the conductive part of the respiratory passages= 150 ml
- Anatomical versus physiological dead space:

On occasion some of the alveoli are none functioning or partially functioning due to absent or poor blood flow so when the alveolar dead space is included, this called physiologic dead space.

"Dead Space" and Its Effect on Alveolar Ventilation

Some of the air a person breathes never reaches the gas exchange areas but simply fills respiratory passages where gas exchange does not occur, such as the nose, pharynx, and trachea. This air is called*dead space air* because it is not useful for gas exchange.

On expiration, the air in the dead space is expired first, before any of the air from the alveoli reaches the atmosphere. Therefore, the dead space is very disadvantageous for removing the expiratory gases from the lungs.

Normal Dead Space Volume.The normal dead space air in a young adult man is about 150 milliliters. This increases slightly with age.

Anatomic Versus Physiologic Dead Space.

The method just described for measuring the dead space measures the volume of all the space of the respiratory system other than the alveoli and their other closely related gas exchange areas; this space is called the *anatomic dead space*. On occasion, some of the alveoli themselves are nonfunctional or only partially functional because of absent or poor blood flow through the adjacent pulmonary capillaries. Therefore, from a functional point of view, these alveoli must also be considered dead space. When the alveolar dead space is included in the total measurement of dead space, this is called the *physiologic dead space*, in contradistinction to the anatomic dead space. In a normal person, the anatomic and physiologic dead spaces are nearly equal

Slide 16

Alveolar ventilation

- ***Rate of alveolar ventilation per min***

  Is the total volume of new air entering the adjacent gas exchange area each minute.
- It = (TV - Dead space volume) x RR

  = 12 (500-150) = 12x 350

  = 4200ml/min

Rate of Alveolar Ventilation

Alveolar ventilation per minute is the total volume of new air entering the alveoli and adjacent gas exchange areas each minute. It is equal to the respiratory rate times the amount of new air that enters these areas with each breath.

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Alveolar ventilation is one of the major factors determining the concentrations of oxygen and carbon dioxide in the alveoli. Therefore, almost all discussions of gaseous exchange in the following chapters on the respiratory system emphasize alveolar ventilation.