MED437
KING SAUD UNIVERSITY

437
PHYSIOLOGY TEAM

Respiratory Ventilation

غيـداء آل مصـمـع
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Revised by

➢ Color index:

Red: important
Green: doctor's notes
Grey: extra information
Pink: found only in female's slides
Blue: found only in male's slides
Yellow: numbers

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Physiology 437 teamwork

Editing file

objectives:

By the end of the lecture you will be able to:

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

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

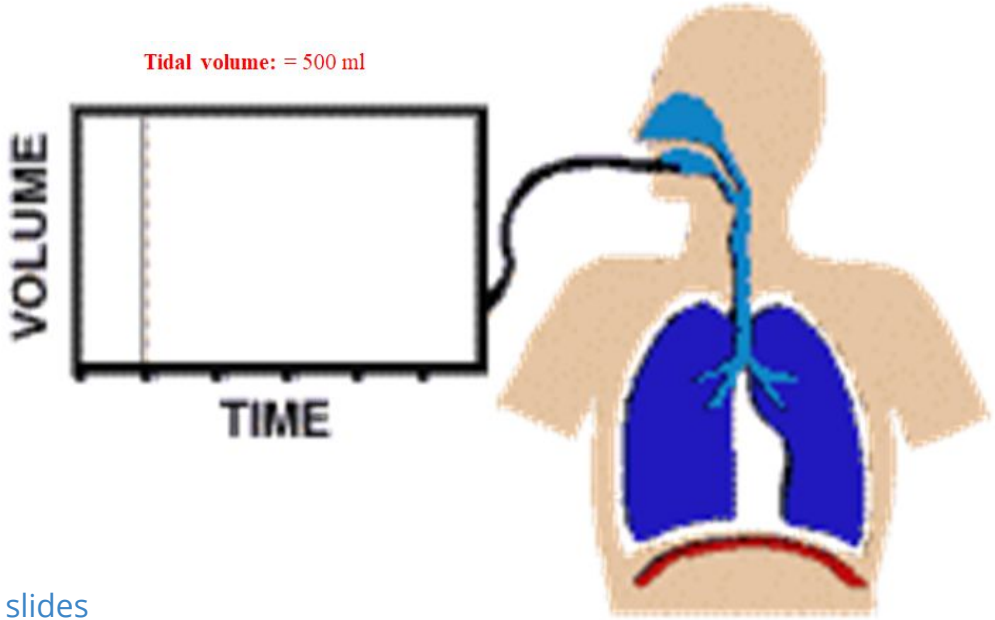
3- Describe FEV1 and its role in differentiating obstructive and restrictive lung diseases.

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.

Pulmonary / Lung Volumes and Capacities



Only in males' slides

animatio
n

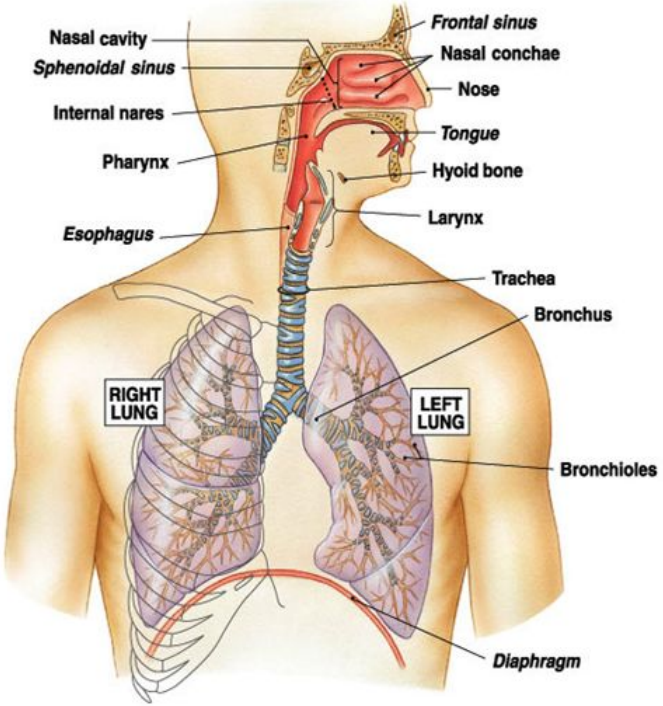
RESPIRATORY SYSTEM

Upper respiratory tract

- Nose
- Pharynx and associated structures

Lower respiratory tract

- Larynx (and the structures below it)
- Trachea
- Bronchi
- Lungs

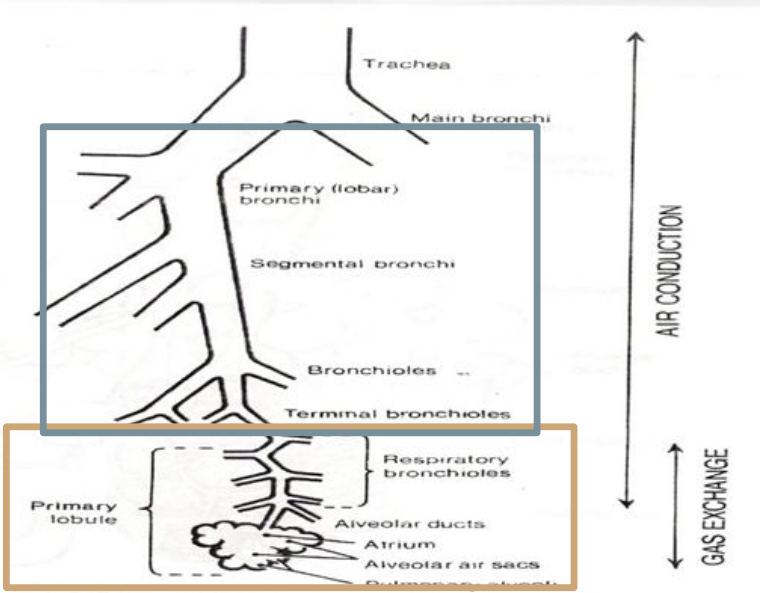


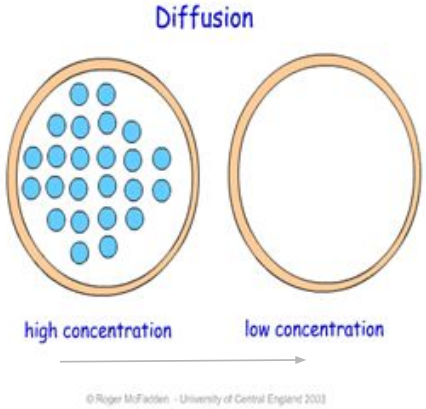
Only in males' slides

Zones of the Respiratory Tract

Only in males' slides

Tidal volume (500ml) = Conductive zone (150ml) + Respiratory zone (350ml)





Gas diffuses in (respiratory zone) from higher concentration (higher pressure) to lower concentration (lower pressure).

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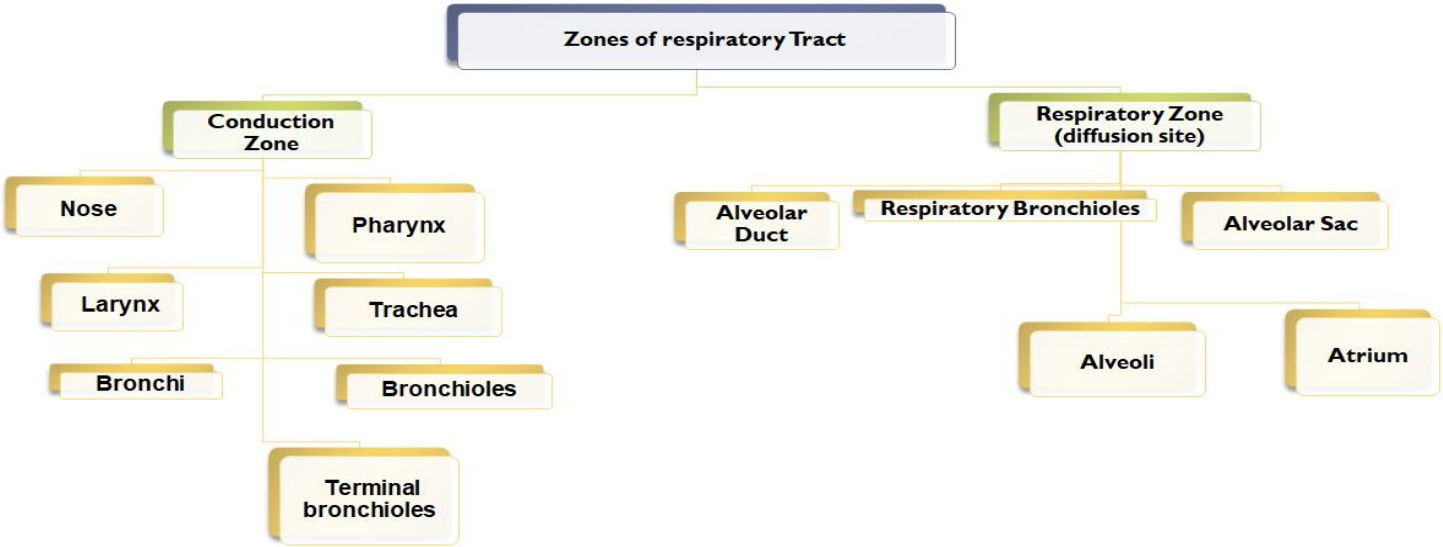
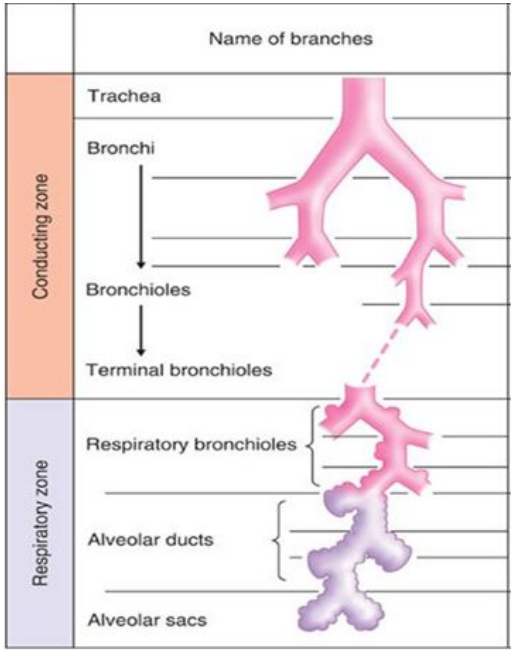

Zones of respiratory Tract
Conduction Zone
Nose
Pharynx
Larynx
Trachea
Bronchi
Bronchioles
Terminal bronchioles
Respiratory Zone (diffusion site)
Alveolar Duct
Respiratory Bronchioles
Alveolar Sac
Alveoli
Atrium

cont..



Tidal Volume (Vt): Normal amount of air we inspire and expire.

The conducting zone: Structures form a continuous passageway for air to move in and out of the lungs.

Respiratory zone:

-Is found deep inside these thin-walled structures; allows inhaled oxygen (O_2) to diffuse into the lung capillaries in exchange for carbon dioxide (CO_2).

- It occupies the space distal to the terminal bronchioles start from the respiratory bronchioles down to the alveolar sacs.
- Where gas exchange takes place.
- Two thirds of the tidal volume is lost here.
- Volume ≅ 350ml/min

Dead space

0:00-3:40

Only in males' slides

Is part of the respiratory tract not participating in gas exchange:

Anatomical dead-space:

Tracheo-bronchial tree down to respiratory bronchioles.

2ml/kg or 150ml in an adult

شبهها الدكتور مثل الماصورة الي تنقل الماء جزء من الماء باقي في الماصورة بس عشان يوصل بعضها

Alveolar dead-space:

Non-perfused alveoli

perfused: supply (an organ or tissue) with a fluid by circulating it through blood vessels or other natural channels.

Physiologic dead-space:

Anatomical dead-space + alveolar dead-space

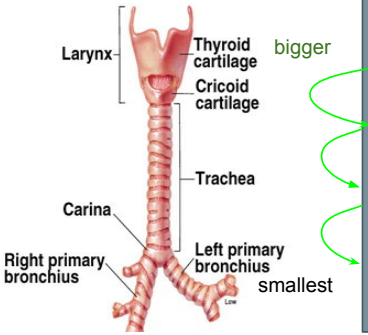
Extra: dead space is the volume of air which is inhaled that does not take part in the gas exchange, either because it (1) remains in the conducting airways, or (2) reaches alveoli that are not perfused or poorly perfused. In other words, not all the air in each breath is available for the exchange of oxygen and carbon dioxide.

No diffusion in "Anatomical Dead Space" is normal

No diffusion in "Alveolar Dead Space" (nonfunctioning alveoli) could be pathological due to edema or fibrosis, or physiological " you don't need all the alveoli in tidal breath".

Pollution and disease pattern

Only in males' slides



Dust particles with an aerodynamic diameter of

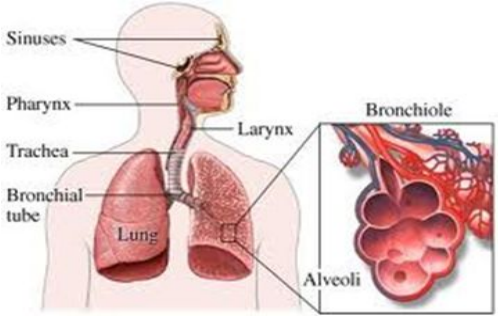
10 micrometer = nose and pharynx.

2-10 micrometer = tracheo-bronchial tree

0.1-2 micrometer within the alveoli.

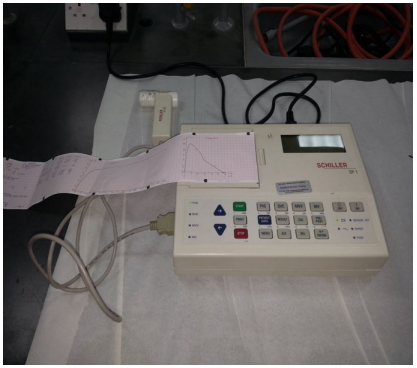
Particles smaller than 0.1micrometer remain in the air stream and are exhaled.

The larynx and carina are very sensitive to dust particles
Terminal bronchioles and even the alveoli are also sensitive to chemical such as sulfur dioxide or chlorine gas.
Air expelled at velocities ranging from 75 to 100 miles / hour [Guyton]
965 Km (600 miles / hour) [Ganong] (more reliable than guyton)



Spirometer

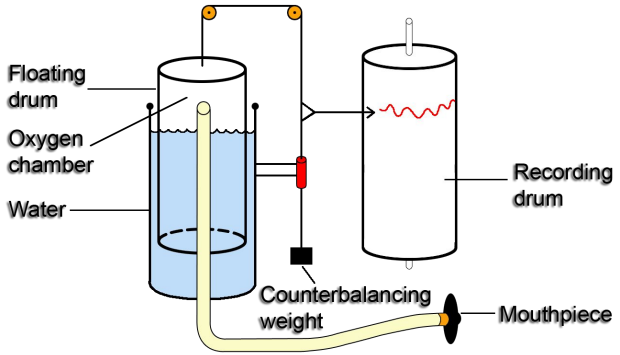
Notes from guyton:
The spirometer consist of a drum inverted over a chamber of water, with the drum counterbalanced by a weight. In the drum is a breathing gas, usually air or oxygen; a tube connects the mouth with the gas chamber. When one breathes into and out of the chamber, the drum rises and falls, and an appropriate recording is made on a moving sheet of paper.



we use the spirometer to measure the lung volume and lung capacity, Except:

1. Residual volume.
2. Functional residual capacity (FRC).
3. Total lung volume (capacity).

The floating drum contains either oxygen or normal air. Counterbalancing weight contains a pen that will move to draw when the patient breath in or out.



Physiological Conditions And Pulmonary Volumes / Capacities

important

Physiology conditions

Age: Pulmonary capacities/Vol keep on increasing until the age of 35 then begins to decrease after the age 35.

Gender: All lung volumes and capacities are about 20 to 25% less in women than in men.

Height: Height increase,increases pulmonary Vol/Cap.

Weight: Weight increase(obesity),decreases pulmonary Vol/Cap.

Ethnic group (Race عرق)

(: الدكتور أثنى على رئاتنا في السعودية)

Exercise: Increases pulmonary Vol/Cap . All lung volumes and capacities are greater in athletic persons than in small and asthenic persons.

Asthenia: physical weakness or lack of energy.

Posture: Pulmonary Vol/Cap while standing is higher than while sitting.

Pregnancy: Decreases pulmonary Vol/Cap.

Diurnal variation, seasonal, climate.

Customary activity.

Geographical location.

Health: If the patient is normal or has lung diseases.

Drs note

The 5 most important information that you need to take

- Age
- Gender
- Height
- Weight
- pregnancy

Physiological Conditions And Pulmonary Volumes / Capacities

4:45

All pulmonary volumes and capacities are about 20 to 25 % less in women than in men, and they are greater in large and athletic people than in small and asthenic people

Lung Volumes

Tidal volume: [VT]
Inspiratory reserve volume [IRV]
Expiratory reserve volume [ERV]
Residual volume [RV]

lung capacities

Vital Capacity [FVC]
Inspiratory capacity (IC)
Functional Residual Capacity [FRC]
Total lung capacity [TLC]

Physiological variations in lung volumes

Lung volumes	Male	Female
Tidal volume	500	500
IRV	3000	2000
ERV	1100	700
Residual volume	1200	1100
TLC	5800	4300

Volume is a single value while capacity is a sum of two or more volumes

The values are important

Pulmonary Volumes

The following 4 volumes when added equal the maximum volume to which the lung can expand

Tidal volume (VT): Volume of air inspired or expired in each normal breath (500 ml)

Inspiratory reserve volume (IRV): extra volume of air, that can be inspired forcefully, beyond the normal tidal volume value (3000 ml)

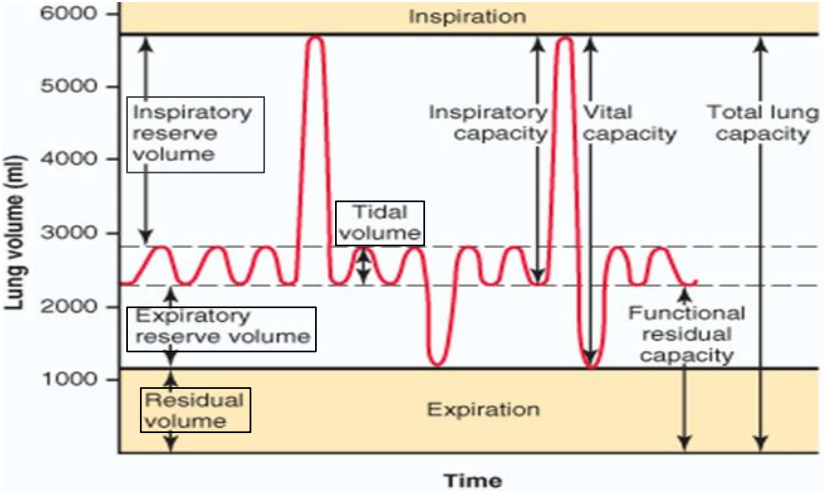
Volume of air inspired by maximal inspiratory effort after normal tidal inspiration

Expiratory reserve volume (ERV): extra volume of air, that can be expired forcefully, beyond the normal tidal volume (1100 ml) Volume of air expired by maximal expiratory effort after normal tidal expiration.

Note that the ERV & the IRV are the values inspired/expired **beyond** the tidal volume and **do not include it.**

Residual Volume (RV): volume of air still remaining in the lungs after a forceful expiration (1200 ml)

The residual volume maintains the structure of the lung and is crucial to the function of the lung.
It **only** leaves the lung in case of drowning or puncture of the lung. (This volume keeps the lung from collapsing)
We cannot measure it by electronic spirometer so it's measured by Helium dilution method



Pulmonary Capacities

Volume is a single value while capacity is a sum of two or more volumes

1- Functional Residual Capacity (FRC): is the amount of air that remains in the lungs at the end of normal expiration = expiratory reserve volume (1100) + residual volume (1200) = 2300 ml. Note the difference between FRC and RV is RV in maximal expiration and FCR in normal expiration

2- Inspiratory Capacity (IC): is the volume of air inspired by a maximal inspiratory effort after normal expiration = inspiratory reserve volume (3000) + tidal volume (500) = 3500 ml.

3- Forced Vital Capacity (FVC): is the maximum amount of air that a person can expel forcefully from the lungs after taking a deep inspiration. The vital capacity = tidal volume + inspiratory reserve volume + expiratory reserve volume = 500 + 3000 + 1100 = 4600 ml. Clinically it's the most importance "diagnosis the diseases"

4- Total lung capacity (TLC): is the maximum volume to which the lungs can be expanded with the greatest possible inspiratory effort. It is the sum of all pulmonary volumes. Tidal volume + Inspiratory + Expiratory reserve volume + Residual volume = 500 + 3000 + 1100 + 1200 = 5800 ml.

The capacity comprises of more than one volume.
All lung capacities and volumes in females are 20% - 25% less than in males.

Cont. Pulmonary Capacities

Forced Expiratory Volume in One Second (FEV1): the volume of air expelled during the first second of a forced expulsion after a maximum inspiration.

This is a very useful volume to test for the diagnosis of obstructive lung diseases, such as emphysema and asthma in which FEV1 is significantly reduced. It is 80%-90% of the vital capacity. FEV1 = 3680 ml.

It is obtained by: 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. (Timed vital capacity)

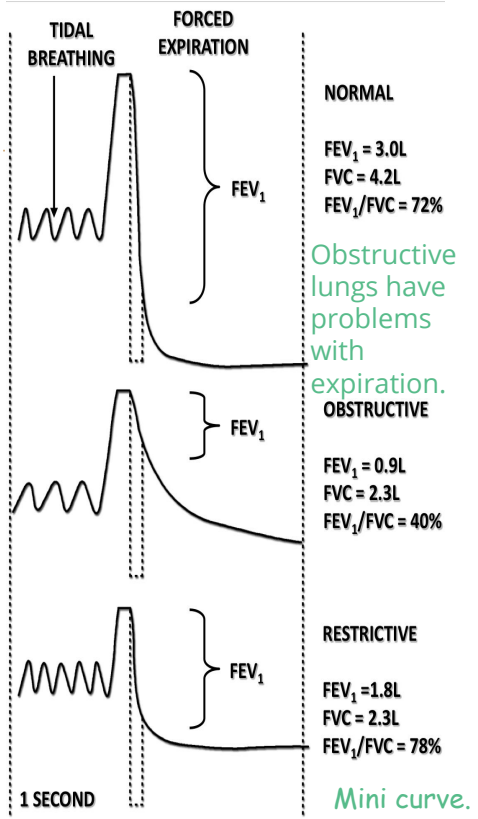
Cont. Pulmonary Capacities

Forced Expiratory Ratio (FEV1/FVC): Normally it is about 80%. The forced expiratory ratio is a sensitive index in differentiating obstructive from restrictive pulmonary disease.

It is:

1. normal or increased in restrictive lung diseases (e.g interstitial pulmonary fibrosis)
2. decreases in obstructive lung diseases (bronchial asthma, emphysema) if it > 80 it's normal. 70-80 mild. 60-70 moderate. <60 severe

Team 436:
REMEMBER ALL THESE 3 PARAMETERS HAVE CLINICAL SIGNIFICANCE:
*Forced Vital Capacity [FVC].
*Forced expiratory volume in one second (FEV1).
*Forced expiratory ratio.



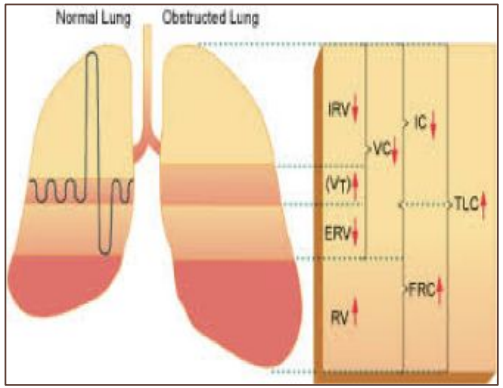
Minute ventilation rate and volume

- **Respiratory rate:** Number of breaths taken per minute, it is normally 12 per minute. [Approximately 12-18/ min]
- **Minute ventilation:** Total amount of air moved into and out of respiratory system per minute
- **Minute respiratory volume (MRV) :** The total amount of new air that moves into the respiratory passages in each minute. It is equal to:

MRV = Respiratory rate x Tidal volume
MRV= RR X TV
= 12 X 500
= 6L/min. (6000 ml/min)

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

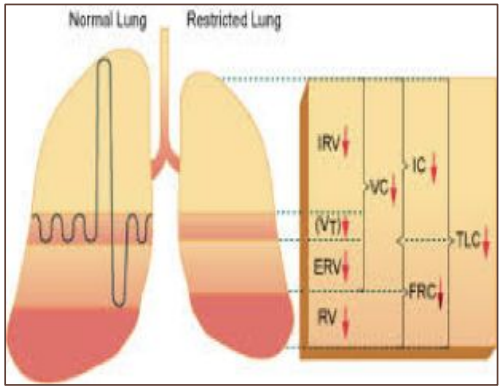
Minute alveolar ventilation in obstructive and restrictive disease



Obstructive disease

causes airway obstruction leading to:

- decrease in airflow into and out of the lungs
- trapping of air inside the lung
- that is why RV, FRC TLC are increased



Restrictive disease

restrict expansion of lungs causing:

- decrease in lung volume (notice the decrease in amount of air according to all parameters)

Pattern of Lung Function Test Parameters in Obstructive and Restricted lung diseases

	OBSTRUCTION	RESTRICTION
FVC	↔ ↓	↓ ↓
FEV1	↓ ↓	↔ ↓
FEV1/FVC	↓	↔ ↑
PEFR	↓ ↓	↔
FEF25-75	↓ ↓	↔ ↓
MVV	↓ ↓	↔ ↓
FRC	↑ ↑	↓ ↓
RV	↑ ↑	↓ ↓
TLC	↑ ↑	↓ ↓

↓ Decreased ↑ Increased ↔ Normal

Dr’s note on restrictive and obstructive patterns

Obstructive disease : at the level of flow

4 disease (chronic obstructive pulmonary diseases) → **COPD:**

1-bronchial asthma 2- emphysema 3- bronchiectasis 4- chronic bronchitis

Restrictive disease: at the level of alveoli

FVC decreased in BOTH

FEV1 decreased in BOTH

FEV1/FCV decreased in RESTRICTIVE - normal or increased in OBSTRUCTIVE

We will study the on details in Pathology don't worry

Closed Circuit Helium Dilution Method

Only in females' slides

C1xV1 = C2xV2

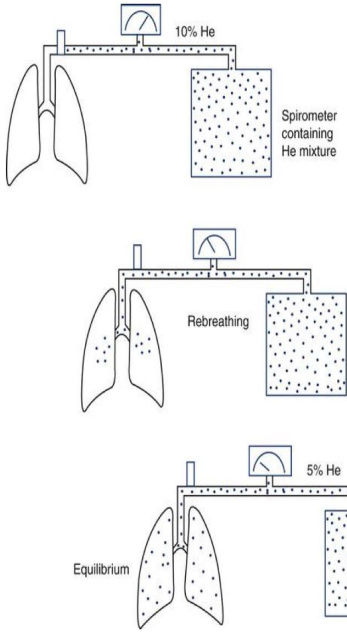
C1: concentration of Hi in spirometry

V1: volume of air in the spirometry

C2: Final concentration of helium

V2 :Volume of spirometry+ FRC

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



- ➔ Used to measure the residual volume. The patient breathes a known volume of air by a spirometer that contains a known
- ➔ concentration of helium. With each breathe the helium will be diluted with the air.
- ➔ The equation is applied when a sample is drawn with constant concentration.

Ci \ i= initial Cf \ f= final

Extra explanation

Closed Circuit Helium Dilution Method

To measure FRC, 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 FRC. At this point, the patient 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 (مختلط يعني بيكون داخل الرئة) by the FRC gases, and the volume of the FRC can be calculated from the degree of dilution of the helium, using the following formula:

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

where **FRC is functional residual capacity**, **CiHe is initial concentration of helium in the spirometer**, **CfHe is final concentration of helium in the spirometer**, and **ViSpir is initial volume of the spirometer**. 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,

RV= FRC - ERV and TLC= FRC+IC

Minute alveolar ventilation rate and volume

1- Rate of Alveolar Ventilation: it is the total volume of new air entering the alveoli and other adjacent gas exchange areas (respiratory zone) each minute.
(Because 1/3 is lost in conductive zone.)

2-Calculating the Rate of Alveolar Ventilation:

- Normal tidal volume : 500 milliliters
- Normal dead space : 150 milliliters
- Respiratory rate : 12 breaths per minute
- Alveolar ventilation equals :

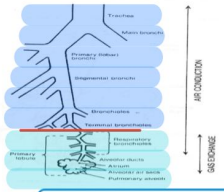
Va = Respiratory rate X (Vt – Vd)
= Respiratory rate X (Vtidal volume – Vdead space)
= 12 X (500 – 150)
= 4200 ml

summary

Zones of the Respiratory Tract (Tidal volume) : Normal amount of air we inspire and expire.
500ml

Conductive zone:
Structures form a continuous passageway for air to move in and out of the lungs.
150ml

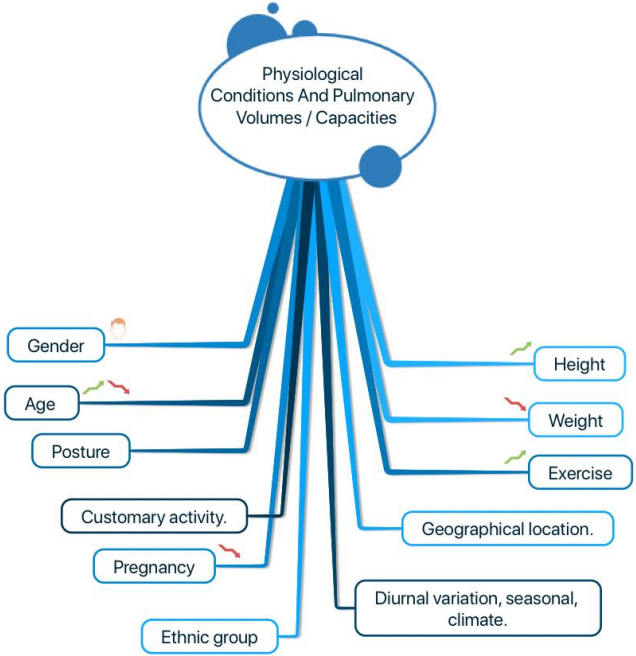
- Nose
- Pharynx
- Larynx
- Trachea
- Bronchi
- Bronchioles
- Terminal bronchioles



Respiratory zone:
Is found deep inside these thin-walled structures allows inhaled(O_2)to diffuse into the lung capillaries in exchange for(CO_2). gas exchange takes place in it.
350ml

- Alveolar Duct
- Alveoli
- Respiratory bronchioles
- Alveolar sac
- Atrium

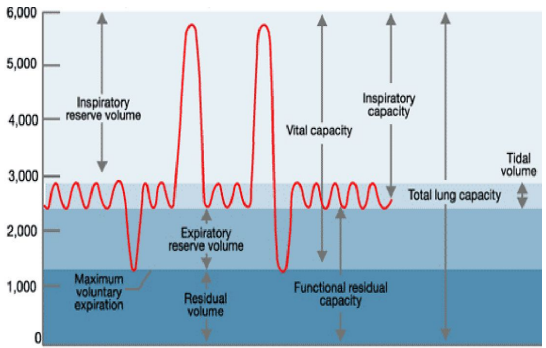
Tidal volume= Conductive zone+Respiratory zone
500ml = 150ml + 350ml



summary Cont...

Physiological variations in lung volumes

Lung volumes	Male	Female
Tidal volume	500	500
IRV	3000	2000
ERV	1100	700
Residual volume	1200	1100
TLC	5800	4300



Pulmonary Volumes and Capacities

lung capacities :

- Inspiratory Capacity
  The volume of air inspired by a maximal inspiratory effort after normal expiration = 3500ml = inspiratory reserve volume + tidal volume.
- Forced Vital Capacity (FVC): is the maximum amount of air that a person can expel forcefully from the lungs after taking a deep inspiration. The vital capacity = tidal volume + inspiratory reserve volume + expiratory reserve volume =500 +3000 +1100=4600 ml.
- Total lung capacity (TLC): is the maximum volume to which the lungs can be expanded with the greatest possible inspiratory effort. It is the sum of all pulmonary volumes. Tidal volume + Inspiratory + Expiratory reserve volume + Residual volume = 500 + 3000 + 1100 + 1200 = 5800 ml.
- Forced Expiratory Ratio (FEV /FVC): (Normally it is about 80% in the first sec.) The forced expiratory ratio is a sensitive index in differentiating obstructive from restrictive pulmonary disease (when vital capacity is abnormal). It is decreased in obstructive lung disease e.g: bronchial asthma, emphysema and is normal or increased in restrictive lung diseas e.g: interstitial pulmonary fibrosis .
- This is the amount (volume)of air that remains in the lungs at the end (after)of normal expiration= the expiratory reserve volume ERV 1100 ml + the residual volume: RV 1200 ml = 2300 milliliters.
- Forced Expiratory Volume in One Second (FEV1): the volume of air expelled during the first second of a forced expulsion after a maximum inspiration.
  This is a very useful volume to test for the diagnosis of obstructive lung diseases, such as emphysema and asthma in which FEV1 is significantly reduced. It is 80%-90% of the vital capacity. FEV1 = 3680 ml.
- Minute Respiratory Volume
  The volume of air breathed in or out of the lungs each minute = respiratory rate x tidal volume = 12 X 500ml = 6000ml/min or 6 L/min.

Lung Volumes :

- Tidal volume: [VT] Volume of air inspired or expired in each normal breath; value = 500 ml or 0.5 L .
- Inspiratory reserve volume [IRV]: It is the extra volume of air, that can be inspired forcefully, beyond the normal tidal volume value= 3000 ml or 3 L.
- Expiratory reserve volume [ERV]: It is the extra volume of air that can be expired forcefully beyond the normal tidal volume.Value = 1100 ml or 1.1 L
- Residual volume [RV]: It is the volume of air still remaining in the lungs after a forceful expiration.Value= 1200 ml.

NOTE

Rate of Alveolar Ventilation:

-Normal tidal volume of 500 milliliters
-Normal dead space of 150 milliliters
-Respiratory rate of 12-18 breaths per minute

NOTE

Gas diffuses in (respiratory zone) from higher concentration (higher pressure) to lower concentration (lower pressure).

Quiz

(1) What happens to a dust particle if it's diameter is smaller than 0.1micrometer ?
(A) remains inside trachea and is exhaled (B) remain in the air stream and is exhaled
(C) remains inside the nose and is exhaled

(2) Which of the following is not a part of the upper respiratory tract?

(A) Larynx (B) pharynx (C) nose

(3) Which of the following volumes remains in the lung during normal breathing & forced breathing:
(A)Tidal volume (B) Residual volume (C) Inspiratory Reserve Volume (D) Expiratory Reserve Volume

(4) What is the MRV and the rate of Alveolar ventilation for a patient with a respiratory rate of 12 breaths per minute?
(A) 6L , 4.2L (B) 60L , 42L (C) 6 ml, 4.2ml. (7) 5L, 3L

Female's team:

Leader: Alanoud Salman Alotaiby

Members:

Ahad Ahmed AlGrain.

Reham Al-Halabi

Durrah Alhamdi

Renad AlMogren

Male's team:

Leader: Abdulhakim AlOnaiq

Members:

Khaled ali showail

Abduljabbar Alyamani

Anas alsaif

Nawaf alluwaymi

Omar Alfawzan