Respiratory Ventilation

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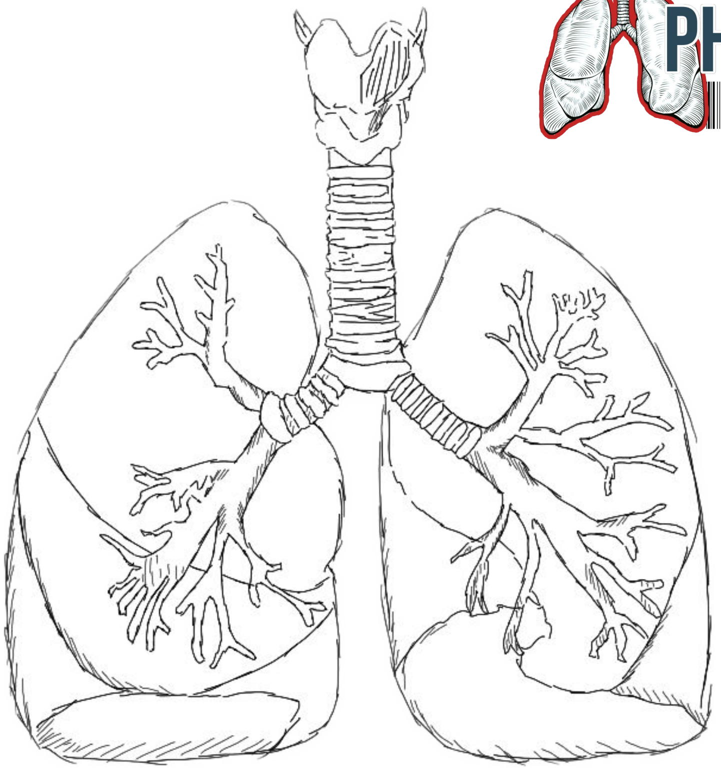


Color Index:
-Main Text -Important -Notes
-Boy Slides -Girl Slides -Extra

Special Thanks to Hasan Alsughayir for the Sketch <3

Male Dr: Ahmed Alsabih
Female Prof: Aida Korish

Objectives

01 Define the various lung volumes and capacities and provide typical values for each

02 Define ventilation rate, their typical values, and their measurement.

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

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

05 Define the term minute ventilation and state a typical value.

06 Distinguish minute ventilation from alveolar ventilation.

Helpful videos from Ninja nerd

Special Thanks to team443

Female`s Dr :more details in practical sessions

Pulmonary Function Tests (PFT)

- Measured by a method called Spirometry:

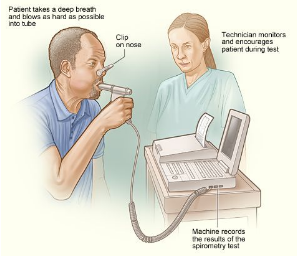
- Used to assess lung function (diagnosis of a disease or the effectiveness of a treatment) & measure their volume.
- There are two types of spirometers: simple (student) & dynamic (in hospitals).
- The readings is presented in the form of a spirogram.

Simple or student spirometer

Dynamic or automatic spirometer

Female's Dr. notes:

- The spirometer consists of a drum (counterbalanced by a weight) inverted over a chamber of water.
- **Inside the drum:** breathing gas (air or O_2) + a tube that connects the mouth with the gas chamber.
- One breathes into & out of chamber → drum rises and falls → an appropriate recording is made on a moving sheet of paper which results in a Spirogram.



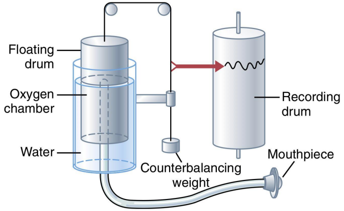


Figure 38-5 Spirometer.

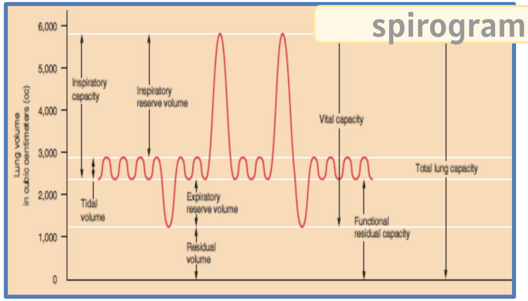
Male's Dr. notes:

Procedure:

a. Preparation: Mouthpiece, Nose clip to make sure there is no leaks, instruct the patient carefully.

b. 3 normal breaths followed by a deep forceful Inhalation followed by a deep forceful exhalation, then deep inhalation, and the test is done.

spirogram



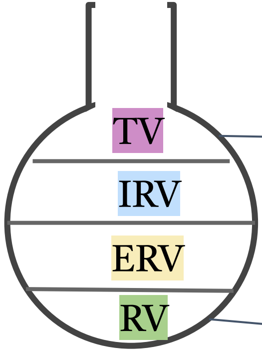
Male's slides: [Video link]

Lung Volume

1 L = 1000 ml

Important Slide

🩺 Doctor said: volumes هي وضعيات التنفس اللي تصير



the air inspired/expired during rest

Impossible to expire

Lung Volumes

Tidal Volume (TV)

Volume of air inspired / expired with each normal breath.

~500ml or ½ L

Composed of resting inspiration & expiration.

Inspiratory Reserve Volume (IRV)

Extra volume of air that can be inspired over the normal tidal volume when person inspires with full force.

~3000ml

Expiratory Reserve Volume (ERV)

Maximum extra volume of air that can be expired by forceful expiration at the end of a normal tidal expiration.

~1100ml

Residual Volume (RV)

Volume of air remaining in lungs after the most forceful expiration.

~1200ml

Can't be measured by spirometer

Pulmonary Capacities

Pulmonary Capacity السعة : two or more lung volumes.

> Doctor said: Female's Dr.: RV came from first breath after delivery, babies take a very strong breath to full ALL the lung (TLC) but after that expired only TV during rest and TV+ERV during exercise (forced) .

Lung Capacities

Can't be measured by spirometer (applies to Total Lung Capacity)

Inspiratory Capacity (IC)

The amount of air a person can breathe in, beginning at normal expiratory level & distending lungs to maximum amount.

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

Functional Residual Capacity (FRC)

The amount of air that remains in lungs after normal tidal expiration.
Acts as a buffer against extreme changes in alveolar gas levels with each breath. And keeps the alveoli partially open.

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

Vital Capacity (VC)

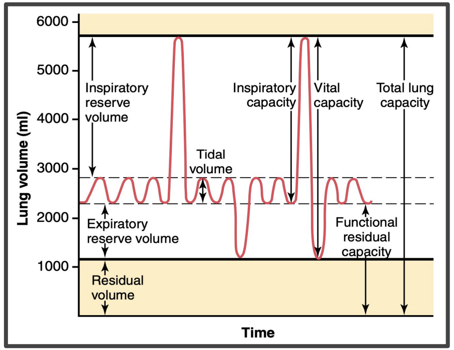
The maximum amount of air a person can expel from lungs after first filling the lungs to their maximum extent & then recording expiring to maximum extent.

VC = TV + IRV + ERV
VC = 500 + 3000 + 1100
VC = 4600 ml
(VC = IC + ERV)

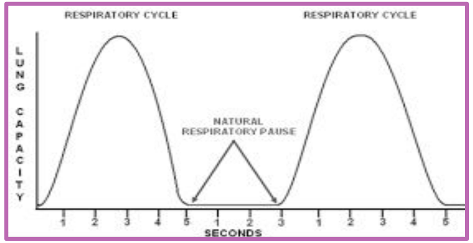
Total Lung Capacity (TLC)

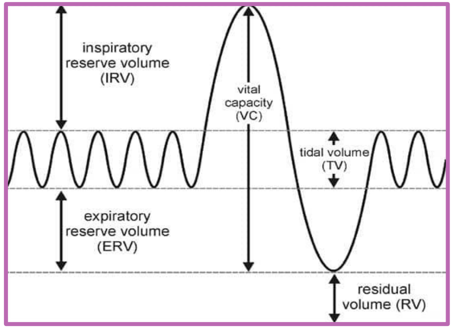
The maximum volume to which the lungs can be expanded with the greatest possible effort.

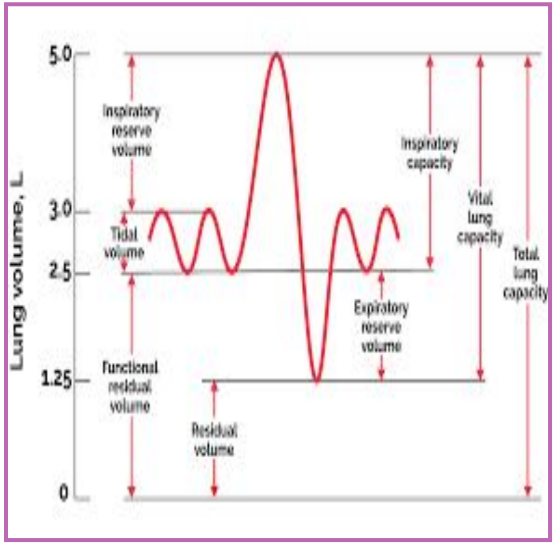
TLC = TV + IRV + ERV + RV
TLC = 500 + 3000 + 1100 + 1200
TLC = 5800 ml

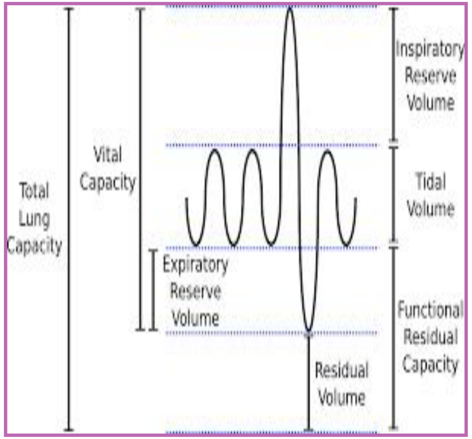


🩺 Doctor said: **Graph name: Spirogram**









Lung Volumes & Capacities

Average Pulmonary Volumes & Capacities

(For a Healthy Young Adult Man)

- 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.

Interrelation Among Pulmonary Volumes & Capacities

From Male Slides

VC = IRV + TV + ERV

VC = IC + ERV

TLC = VC + RV

TLC = IC + FRC

FRC = ERV + RV

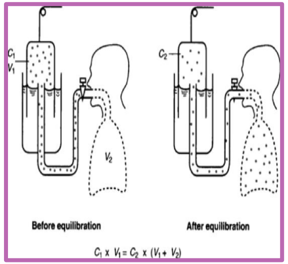
Pulmonary Volumes and Capacities	Normal Values (ml)
Volumes	
Tidal volume	500
Inspiratory reserve volume	3000
Expiratory volume	1100
Residual volume	1200
Capacities	
Inspiratory capacity	3500
Functional residual capacity	2300
Vital capacity	4600
Total lung capacity	5800

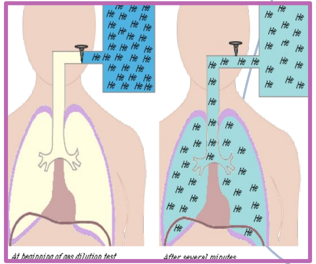
Determination of the FRC, RV, TLC

🩺 Female`s Dr: will be discussed in practical sessions.

Female Slides Only

Method: Closed Circuit Helium Dilution method.





$$C_1 \times V_1 = C_2 \times V_2$$

- C_1 : Concentration of He in spirometry
- V_1: Volume of Air in the spirometry
- C_2 : Final Concentration of Helium
- V_2: Volume of spiremetry + FRC

$$FRC = \left(\frac{C_i He\ (C_1)}{C_f He\ (C_2)} - 1 \right) \times V_i Spi\ (V_1)$$

FRC = ERV + RV

-ERV

RV = FRC - ERV

443: RV can't be measured directly with a spirometer.
He is added to air in the device → gas is inhaled until equilibrium is reached between He in spirometer & lungs → completely expired to measure RV.

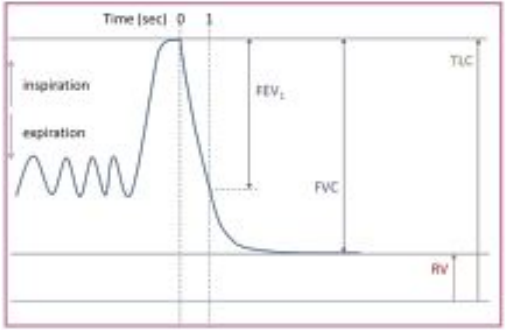
Example:

If $C_1 = 10$
$C_2 = 5$
$V_1 = 2000$
ERV = 1100

$FRC = [(C_1 / C_2) - 1] \times V_1$
$= [(10/5) - 1] \times 2000$
$= 2000$

RV = FRC - ERV
= 2000 - 1100

FVC & Forced Expiratory Volumes (FEV)
(Timed Vital Capacity)



Scenario

A person is asked to inspire as deeply as possible then to breath out as hard and fast as he can. Expiration is continued until he expired all the air out → Forced Vital Capacity is obtained.

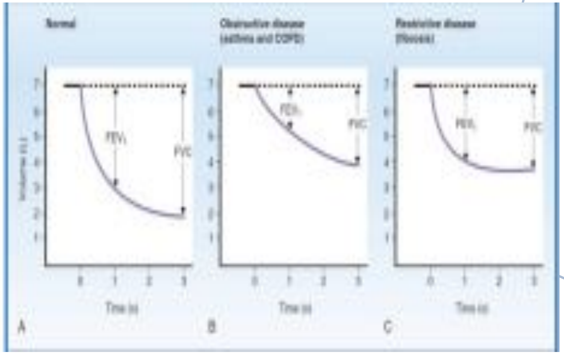
- Forced Vital Capacity (FVC) is the total amount of air exhaled during the FEV test.

■ **<u>During this process:</u>**

- **FEV1**: volume of air that can be forcibly expired in the first second.
- **FEV2**: cumulative volume expired in 2 seconds.
- **FEV3**: cumulative volume expired in 3 seconds.
- Normally, the entire vital capacity can be forcibly expired in 3 seconds → there is no FEV4

FEV/FVC Ratio

FEV1/FVC: fraction of vital capacity that can be expired in the first second.



Importance:

- FVC & FEV1 are useful indices of lung disease.
- Differentiate between obstructive & restrictive lung diseases.

Normal person:

- FEV1/FVC: 0.8 or 80% (80% of VC can be expired in first second of forced expiration).

Patient with Restrictive Lung Disease:

- FEV1/FVC: Normal or increased
- Both FEV1 & FVC are decreased, but FEV1 decreases less than FVC.
- Example: interstitial pulmonary fibrosis.

Patient with Obstructive Lung Disease:

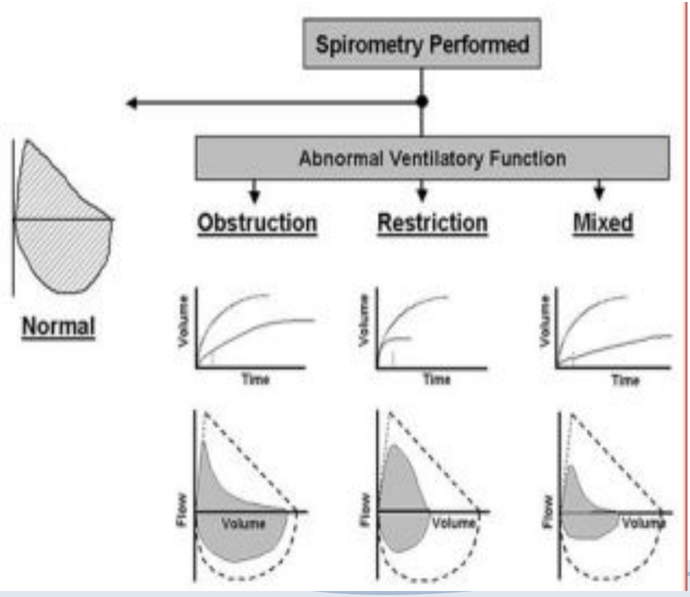
- FEV1/FVC: decreased
- Both FEV1 & FVC are decreased, but FEV1 decreases **more** than FVC.
- Example: bronchial asthma & Chronic Obstructive Pulmonary Disease (Emphysema).

Typical of airway obstruction with its increased resistance to expiratory air flow.

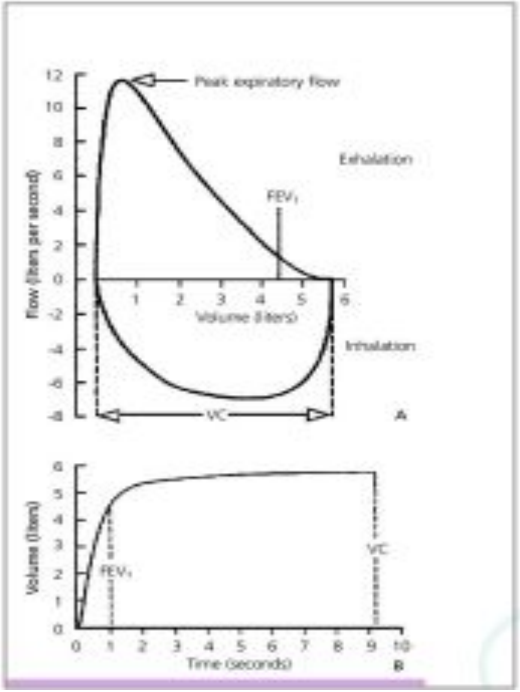
Spirometric Flow Diagram

<u>Important</u> (figures may come in the exam)

This figure below obtained by spirometry method is for the differentiation between Obstructive, Restrictive and Mixed lung diseases. Each Lung Disease Type has unique diagram.



Interpretation:
1. Obstructive: we see in the flow-volume diagram a concavity (characteristic of obstructive lung diseases) resulted from rapid decrease in the flow rate (Liter/second) and this will result in much lower FEV1, and we also see a decrease in the total volume expired (Vital Capacity).
2. Restrictive:
in the flow-volume diagram we see convexity (characteristic of Restrictive lung diseases) meaning that the flow rate decreased but less rapidly than in obstructive, so FEV1 will decrease but not as much as in obstructive, and the Vital Capacity (total volume expired) decreased much more than in obstructive.
3. Mixed: we see in flow-volume diagram "DNA" from both, VC decreased severely (as in Restrictive LD) and the Concavity is present (as in Obstructive LD).



Normal spirometric flow diagram. (A) Flow-volume curve. (B) Volume-time curve

Minutes Respiratory Volume (MRV)

MRV | Respiratory Rate x Tidal Volume

MRV: the volume of air that enters the respiratory passages (in and out of the lung) per minute.

- MRV = RR x TV
  MRV = 12 x 500
  MRV = 6000 ml/min

- It could rise to 200 L/min or more than 30 times normal (more than normal value):
  200,000 ml/min

- If RR = 40
  & TV = 4600 ml in young adults man (due to exercise)

- MRV = RR × TV
  MRV = 40 × 4600
  MRV = 200 L/min

Rising of MRV could happen during daily exercise or pathologic condition

Dead Space & Alveolar Ventilation

Dead Space | Volume of air not participating in gas exchange.

Anatomical Dead Space (in the structure): volume of air present in the conducting respiratory passages
(150 ml = ⅓ of tidal volume).

- <u>On expiration</u>: this air is expired first, before any of the air from alveoli reaches the atmosphere.

Non-Functioning Alveoli/Functional Dead Space: alveoli that cease to act in gas exchange. Why?

- Because they are not perfused by capillary blood supply.
- Due to collapse or obstruction.

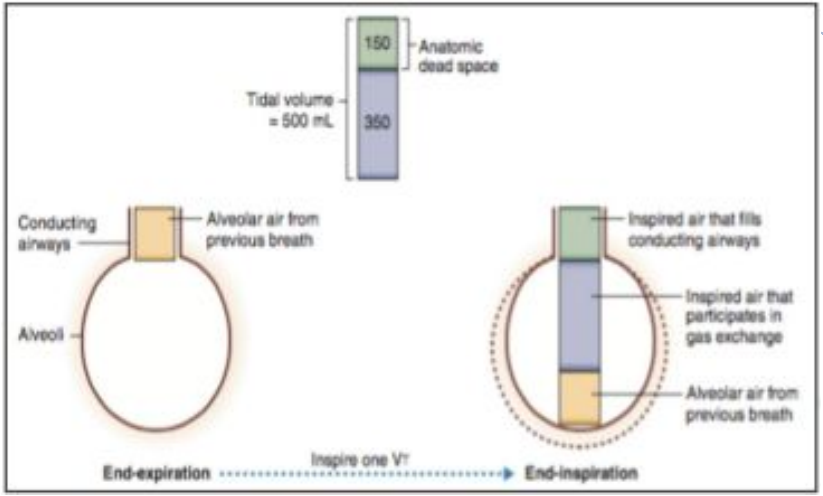
Physiological Dead Space: summation of non-functioning alveoli/alveolar dead space & anatomical dead space.

- <u>In healthy subjects</u>: anatomical dead space = physiological dead space

Alveolar Ventilation

Rate of Alveolar Ventilation per minute: total volume of new air entering adjacent gas exchange area (respiratory zone) each minute.

Rate = (TV - Dead Space Volume) × RR
Rate = (500 - 150) × 12
Rate = 4200 ml/min
Rate = 4.2 L/min



Alveolar ventilation is one of the major factors determining the concentrations of O_2 & CO_2 in alveoli.

MCQs

Q1:Which one of the lung volumes prevented it from collapse after forced expiration?			
A-Expiratory reserve volume.	B-Inspiratory reserve volume.	C-Residual volume.	D-Tidal volume.
Q2:What is the normal value for VC ?			
A-4500ml	B-3500ml	C-2300ml	D-5800ml
Q3:A 34 year old male breathes 15 times per minute. His FRC is 3000 and his tidal volume is 550. What is his alveolar ventilation per min (knowing that the dead space is 150)?			
A-4L/min	B-8L/min	C-6L/min	D-10L/min

1-C 2-A 3-C

MCQs

Q4: A 68 years old patient came with a lung disease, after examination it was revealed that he had normal/increased FEV/FVC ratio. which of the following categories of lung diseases would you say he has ?			
A-No lung disease(normal)	B-Mixed	C-Obstructive Lung Disease	D-Restrictive Lung Disease
Q5: Assuming a respiratory rate of 12 breaths/min, calculate the minute ventilation.			
A- 6 L/min	B- 1 L/min	C- 500 L/min	D- 1 L/min
Q6: A patient has a dead space of 150 milliliters, FRC of 3 liters, tidal volume (TV) of 650 milliliters, expiratory reserve volume (ERV) of 1.5 liters, total lung capacity (TLC) of 8 liters, and respiratory rate of 15 breaths/ min. What is the residual volume (RV)?			
A- 500 milliliters	B- 3000 milliliters	C- 2750 milliliters	D- 1500 milliliters

4-D 5-A 6-D

SAQs

Q1: Compare between FEV/FVC ratio of Restrictive Lung Disease & Obstructive Lung Disease

Q2: What are the Residual Volume and what is the benefit of it?

Q3: What is the method that enables us to measure the RV & FRC & TLC and why?What is the method that enables us to measure the RV & FRC & TLC and why?

A1: on slide 1o

A2: is the volume of air remaining in lungs after the most forceful expiration. It is useful in the process of gas exchange in case of poor oxygen, because it will always remain inside the lung, so it's prevent the lung collapsing.

A3: RV is Impossible to expire from lung. So, we can NOT measure it by Spirometry. Instead, the only method to measure any quantity which contain RV is by Closed Circuit Helium Dilution. RV is Impossible to expire from lung. So, we can NOT measure it by Spirometry. Instead, the only method to measure any quantity which contain RV is by Closed Circuit Helium Dilution.

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