Pulmonary function tests (PFTs)

Lecture Objective

- Definition of PFTs, indication & contraindications
- Definition of Lung volumes & capacities.
- Spiromitry & How to use to measure lung volume & capacity
- Dead Space & DLCO and How to measure them .
- The effect of some respiratory disease on Spirograph.

Definition

Pulmonary function tests (PFTs) are noninvasive tests that show how well the lungs are working.

The tests measure lung volumes, capacities, rates of flow, and gas exchange.

Important pulmonary studies

Standared:

- Spirometry
- Peak expiratory flow(flow volume loop)
- Diffusing capacity of carbon monoxide (DLCO)

Specialized:

- Arterial blood gas
- Pulse oximetry
- ventilation- perfusion (V/Q) scan
- Methacholine challenge

Indications of PFTs

1. Investigation of patients with signs and symptoms that suggest pulmonary disease e.g. cough, wheeze, breathlessness, crackles, abnormal chest x-ray

2. Monitoring patients with known pulmonary disease for progression and response to treatment e.g. interstitial fibrosis, COPD, asthma , pulmonary vascular disease

3. Investigation of patients with disease that may have respiratory complications e.g. connective tissue disorders, neuromuscular diseases

4. Preoperative evaluation prior to surgeries e.g. lung resection, abdominal surgeries, cardiothoracic surgeries ,etc..

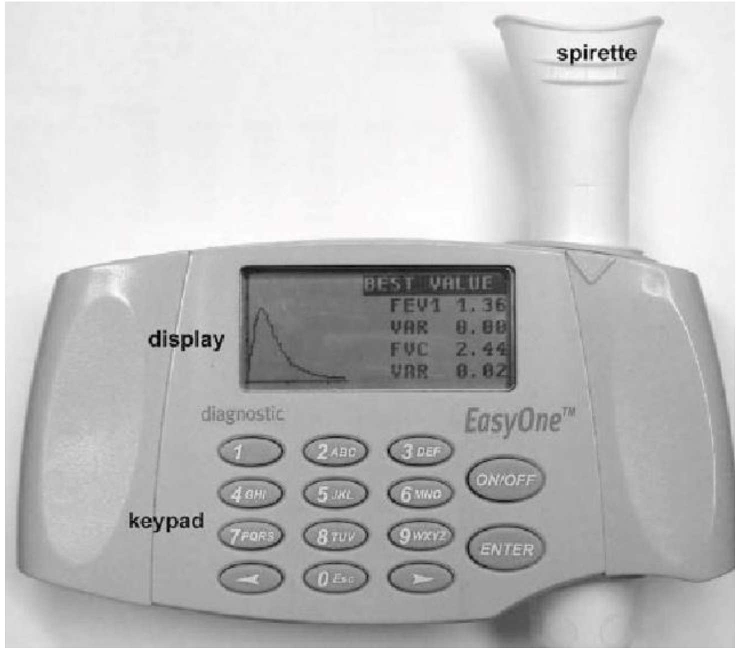
5. Evaluation of patients with a risk of lung diseases: exposure to radiation, toxins, smoking, medications, environmental or occupational exposures, etc. ..

6. Surveillance following lung transplantation to assess for : acute rejection, infection, obliterative bronchiolitis

Contraindications of PFTs

- Myocardial infarction within the last month
- Unstable angina
- Recent thoraco-abdominal surgery
- Recent ophthalmic surgery
- Thoracic or abdominal aneurysm
- Current pneumothorax

Spirometry


spirette
display
keypad
BEST VALUE
FEV1 1.36
VAR 0.00
FVC 2.44
VAR 0.02
diagnostic
EasyOne™
ON/OFF
ENTER


EasyOne Pro

Spirometry is the most common of the pulmonary function tests (PFTs).

Spirometry is an instrument that measures how much air you inhale, how much you exhale and how quickly you exhale to determine lung function. It can directly measure all lung volumes and capacities except those which include residual volume in their measurements. (RV, TLC and FRC can't be measured directly)

Human variations

Lungs volumes and capacities are not identical in every human being and they vary according to different variables:

- Age : lung measurements and functions decline with age.
- Height : size varies with height.
- Gender : males have larger lungs compared to females.
- Race : white people have much larger lungs than black people.

WHY DO WE DO SPIROMETRY?

Spirometry is helpful in assessing breathing patterns that diagnose conditions such as:

- Asthma
- Pulmonary fibrosis.
- Cystic fibrosis.
- Chronic obstructive pulmonary diseases (COPDs).

- Follow the natural history of disease in respiratory conditions
- Assess of impairment from occupational asthma
- Spirometry is useful to differentiate between Respiratory from cardiac disease as the cause of breathlessness
- Conduct pre-operative risk assessment before anesthesia or cardiothoracic surgery
- Measure response to the treatment of conditions which spirometry detects

Spirometry protocol

1.Check patient information:

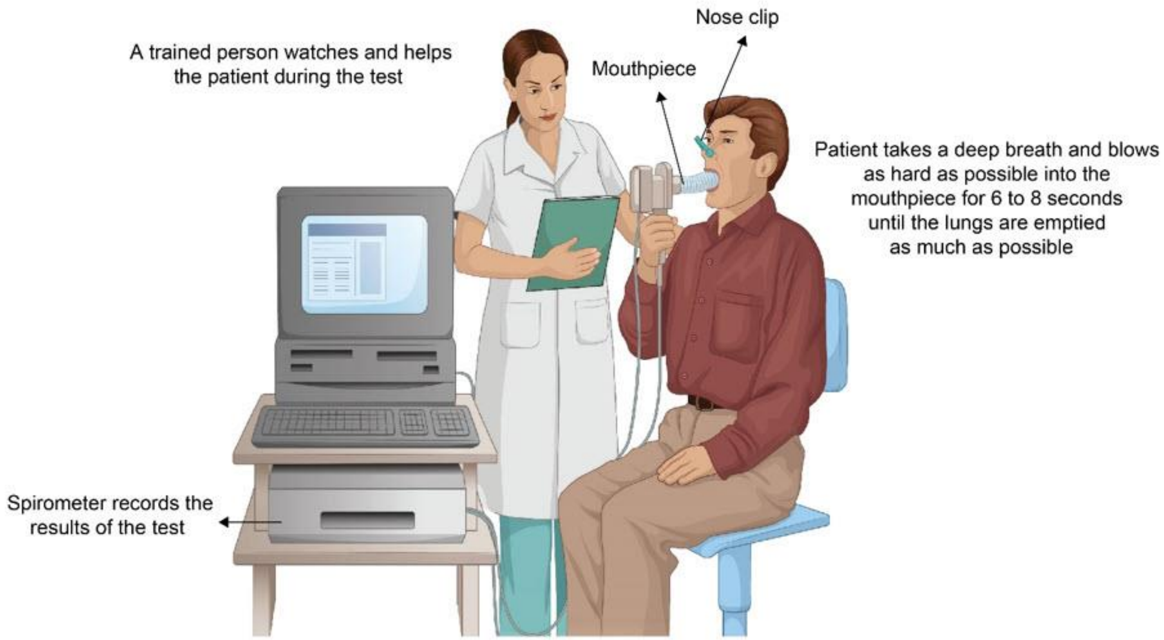
- Age
- Gender
- Race
- Height

2.Things that patient should avoid prior to spirometry:

- Smoking
- Alcohol
- Medication use
- Eating a large meal
- Heavy exercising

3.Correct patient positioning:

- Sit upright
- Feet flat on floor with legs uncrossed
- Loosen tight-fitting clothing



4.Give the patient instructions throughout the procedure to enhance the result

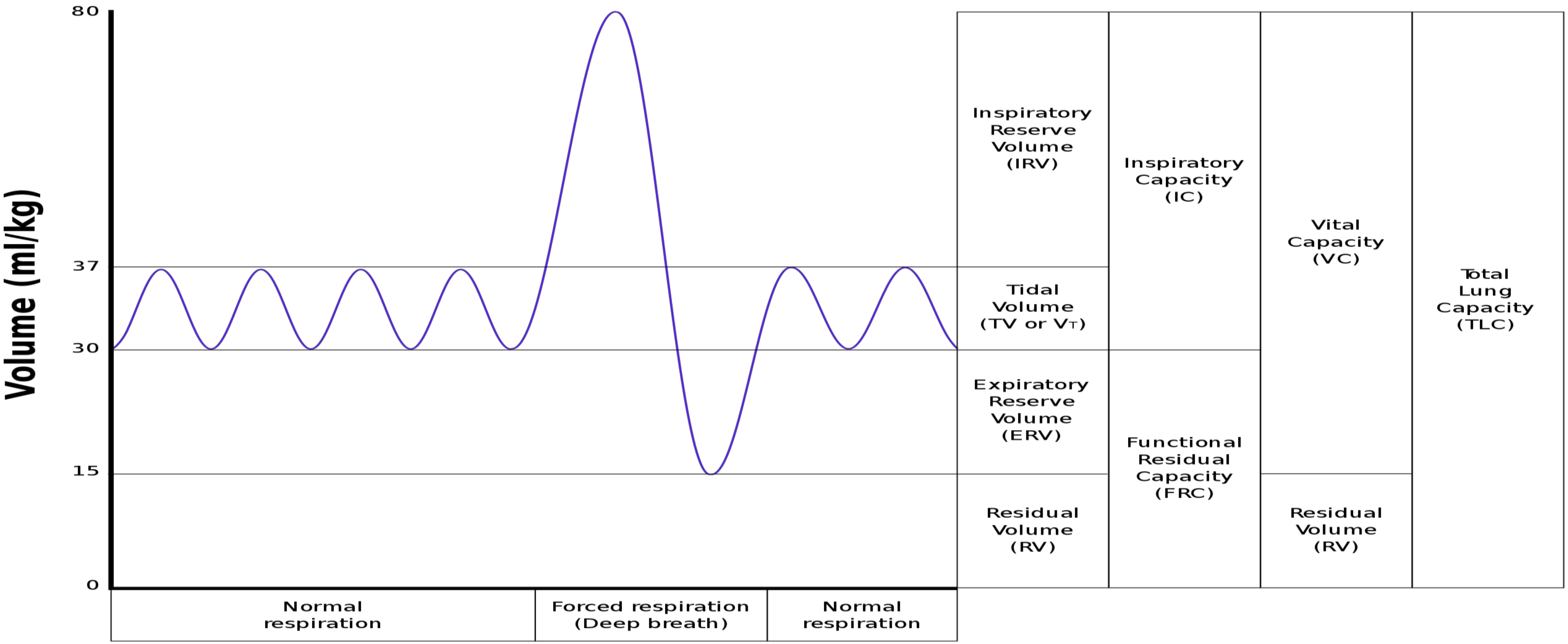
5.Correct spirometry technique:

- The patient will place a clip on his nose to prevent air leakage from his nostrils.
- Then, he will take a deep breath filling his lung completely with air and hold it. : *Adults should blow air for at least 6 seconds. *Children (≤10 years) should blow air for 3 seconds.
- A spirometer mouthpiece will be placed between his teeth.(lips should tightly enclose the device to ensure there is no air leakage).
- Finally, the patient should exhale as hard and as fast as he can until he is told to stop. *For accurate result, the test should be performed 3 times, and the highest values are recorded.

Lung volumes also known as “respiratory volumes”

- Definition: It refers to the volume of gas in the lungs at a given time during the respiratory cycle.
- The average total lung capacity of an adult human male is about 6 litres of air.
- These volumes tend to vary, depending on many factors.

Lung Volumes And Capacities Chart



Definitions:
Lung volumes

- **Tidal volume (TV):** It is the amount of air that can be inhaled or exhaled during one respiratory cycle during <u>**quiet**</u> breathing, It's approximately 500ml.
- **Inspiratory reserve volume (IRV):** It is the amount of air that can be <u>**forcibly**</u> inhaled after a normal tidal volume, It's approximately 3000 ml.
- **Expiratory reserve volume (ERV):** It is the volume of air that can be exhaled <u>**forcibly**</u> after exhalation of normal tidal volume, It's approximately 1200 ml.
- **Residual volume (RV):** It is the volume of air remaining in the lungs after <u>**forcibly**</u> exhaling, It's approximately 1200 ml.
- **Note: A number of the lung volumes can be measured by <u>Spirometry:</u> (Tidal volume, Inspiratory reserve volume, and Expiratory reserve volume), measurement of Residual volume, Functional residual capacity, and Total lung capacity is through body plethysmography, nitrogen washout and helium dilution technique.**

Definitions
Lung capacities

- **Total Lung capacity (TLC):** It is the maximum volume of air in the lungs after **<u>forcibly</u>** (maximum) inhaling beyond normal tidal volume, can be calculated from the sum of tidal volume, inspiratory reserve, expiratory reserve and residual volumes,(TLC = TV+IRV+ERV+RV) It's approximately 6000 ml.
- **Inspiratory capacity (IC):** It is the maximum volume of air that can be **<u>forcibly</u>** inhaled following a resting state (after expiration), can be calculated from the sum of inspiratory reserve volume and tidal volume (IC = IRV+TV), It's approximately 3500 ml.

Definitions
Lung capacities cont'd

- **Function Residual Capacity(FRC):** It is the amount of air remaining in the lungs at the end of a <u>**quiet**</u> (normal) exhalation, can be calculated from the sum of residual and expiratory reserve volumes,(FRC = RV+ERS), It's approximately 2400 ml.
- **Vital Capacity(VC):** It is the total amount of air exhaled after maximal inhalation, can be calculated from the sum of tidal, inspiratory reserve, and expiratory reserve volumes ,(VC = TV+IRV+ERV), It's approximately 4800 ml.

- **Note: all lung volumes and capacities varies according to many factors.**
- **NOTE: the difference between volumes and capacity is the capacity is the summation of two or more of the volumes.**

How to measure FRC

Helium dilution test:❖

A spirometer with a given volume is mixed with Oxygen and Helium at a certain concentration .

Before breathing from the spirometer the person expires normally .

At the end of tidal expiration , the volume in the lung = FRC

At this point the subject immediately begins to breathe from the spirometer (gases in the spirometer mixes with gases of the lung)

RV = FRC – ERV

TLC = FRC +IC

Determination of functional residual capacity:

- The functional residual capacity cannot be measured by spirometer because the air in the residual volume of the lungs cannot be expired into the spirometer. Measurement is achieved by helium dilution method (Helium is a gas which is neither produced nor reabsorbed by the body).
- The used formula;

$$C_1 V_1 = C_2(V_1 + \mathrm{FRC})$$
$$\Rightarrow \mathrm{FRC} = V_1 \frac{C_1 - C_2}{C_2}$$

$$FRC = \left(\frac{Ci_{He}}{Cf_{He}} - 1\right) Vi_{spir}$$

- Where:
- CiHe = initial concentration of He in the spirometer
- CfHe = final concentration of He in the spirometer
- Vi spir = initial volume of the spirometer

The Forced Vital Capacity (FVC):

--FVC is one of the most useful measurements to assess ventilatory function of the lungs. •

--To measure FVC, the person inspires maximally and then exhales into the spirometer as forcefully, rapidly, and completely as possible. •

--additional measurements can be obtained from the FVC spirogram. •

1-Forced expiratory volume of air exhaled in 1 second (FEV1). •

FEV1 has the least variability of the measurements obtained from a forced expiratory maneuver and is considered one of the most reliable spirometry measurements. •

FEV1 is usually presented as a percentage of FVC (i.e., FEV1/FVC × 100). Normally the FEV1/FVC ratio is 80%. •

2- Peak expiratory flow rate (PEFR)

A test that measures how fast a person can exhale (breathe out).

-3 Forced expiratory flow (FEF25–75).

FEF25–75 has the greatest sensitivity in detecting early airflow obstruction. This measurement represents the expiratory flow rate over the middle half of the FVC (between 25% and 75%). •

Measurements of FVC,FEV1, FEV1/FVC ratio, are used to detect obstructive and restrictive pulmonary disorders •

##After spirometry technique is done and values are collected, the following graphs will be produced.

**The graphs below show normal results.

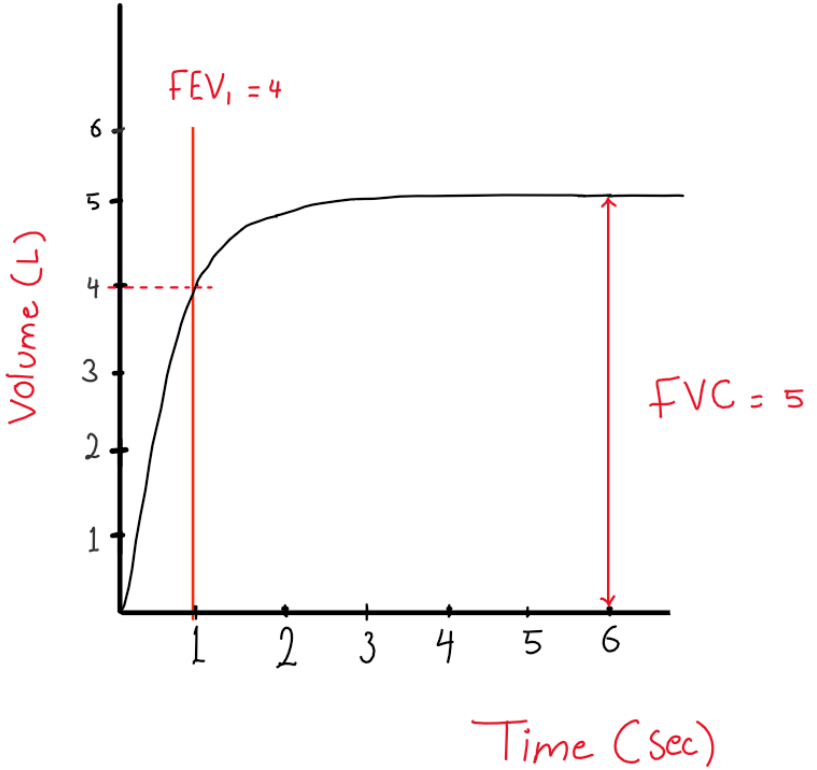
*Volume-Time curve

Normally most of air is expired at the first second

→FEV1= 4L

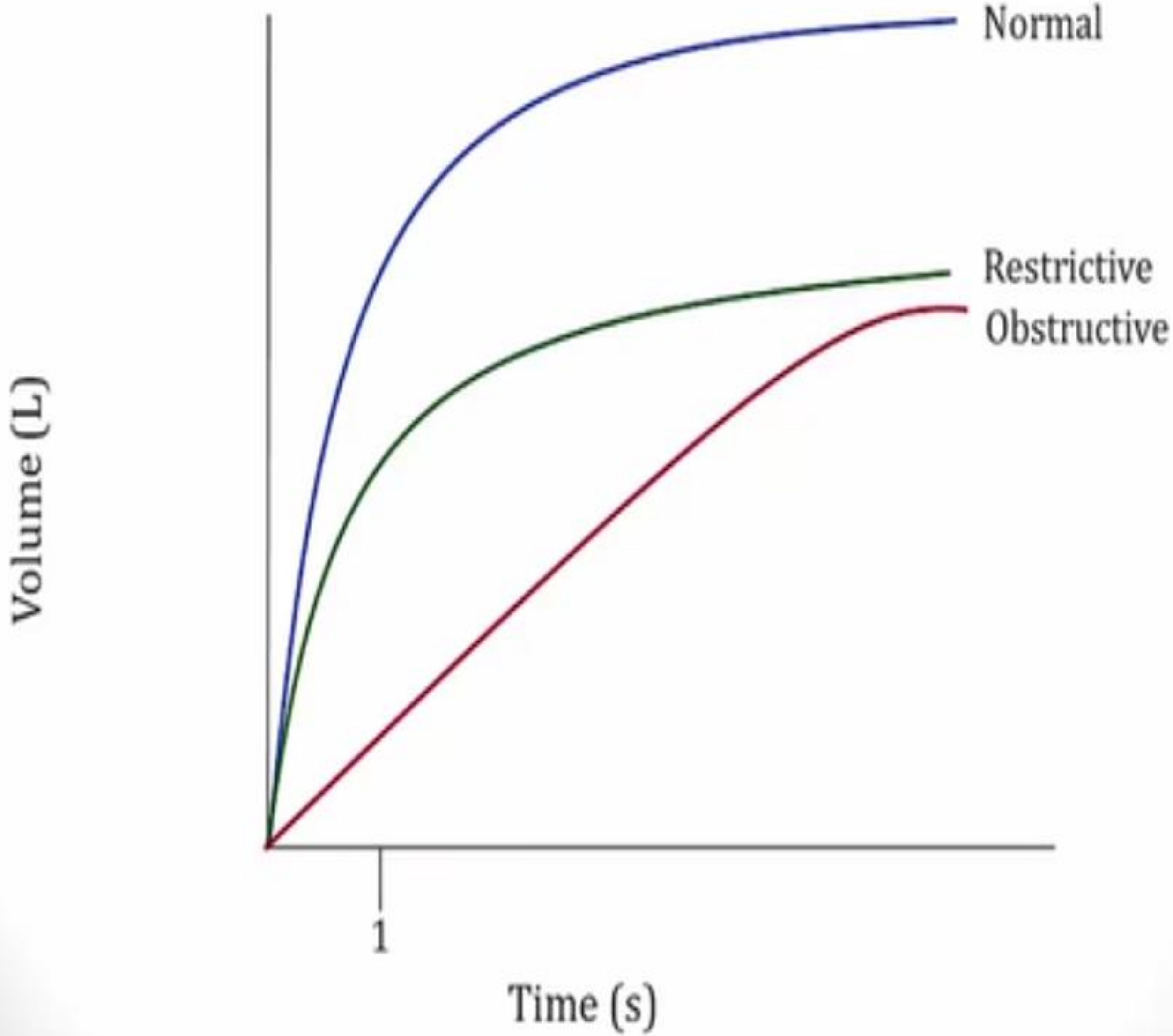
→FVC= 5L

→FEV1/FVC ratio=0.8=80%

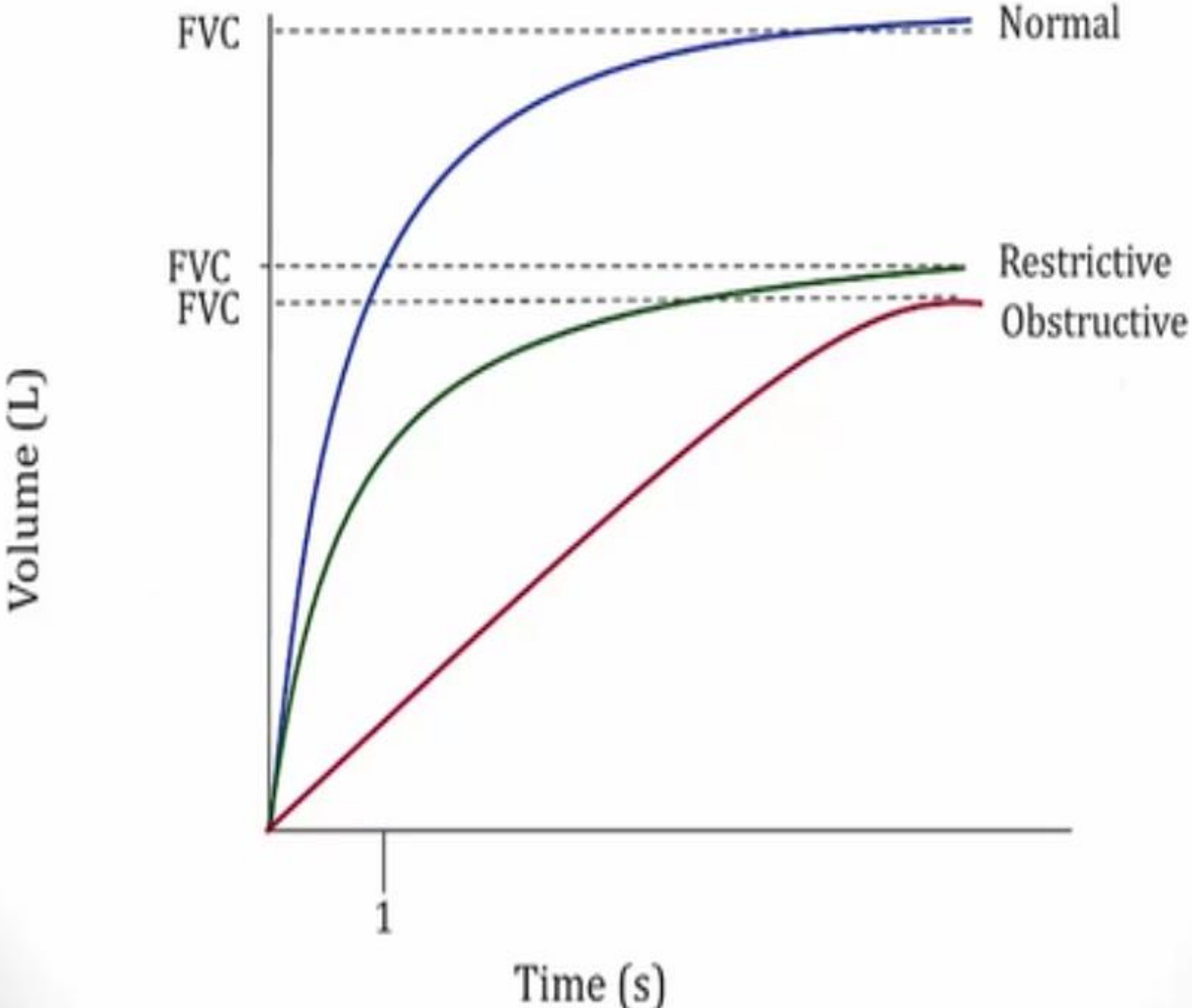


Volume – Time curve

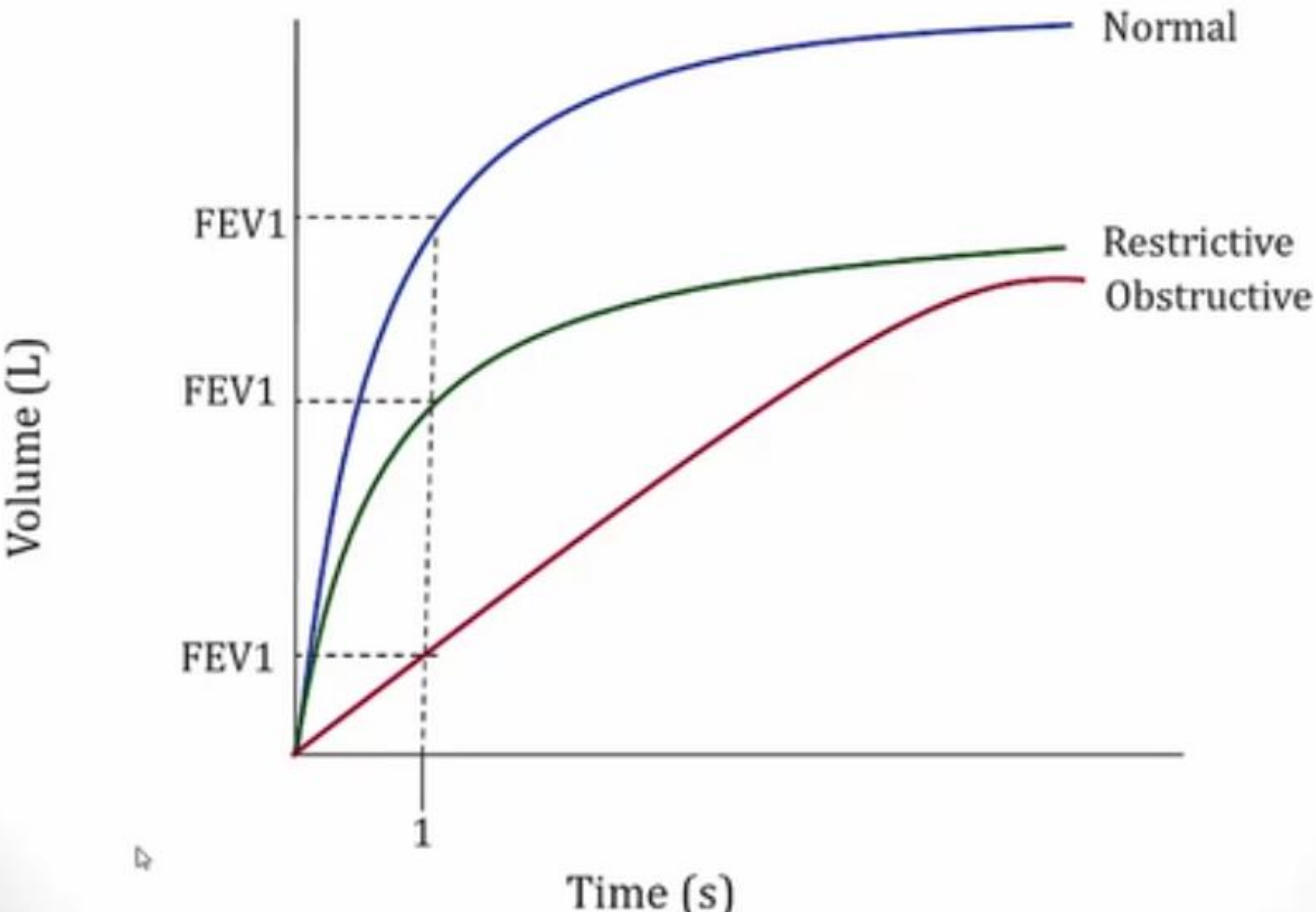
Spirometry



Spirometry


FVC
Normal
FVC
Restrictive
FVC
Obstructive
Volume (L)
1
Time (s)

Spirometry


Normal
Restrictive
Obstructive
FEV1
FEV1
FEV1
Volume (L)
1
Time (s)

Summary

- FEV1 and FVC fall in both obstructive and restrictive diseases
- FEV1 falls MORE than FVC in obstructive

	FEV1	FVC	FEV1/FVC
Obstructive	↓↓	↓	↓
Restrictive	↓	↓	>80%

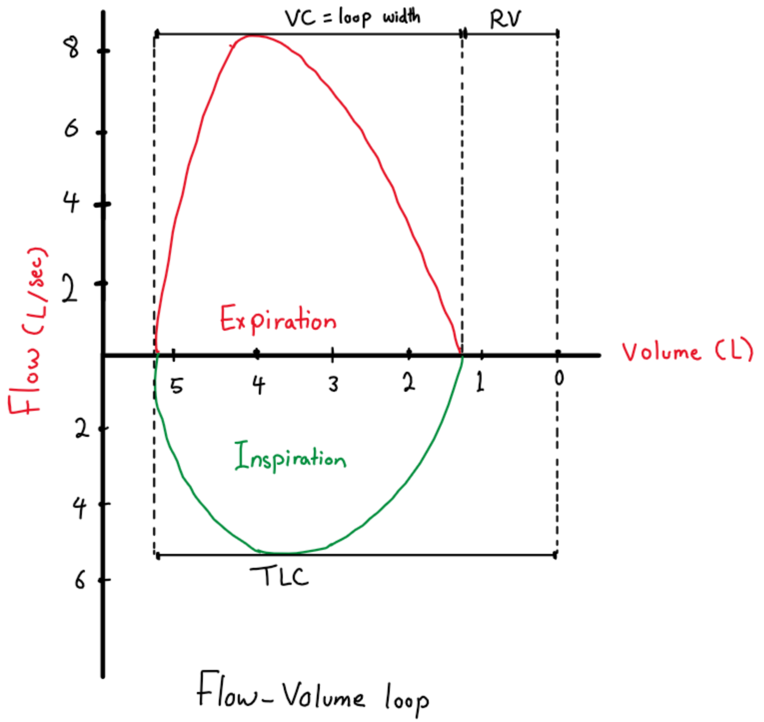
*Flow-Volume loop

It is a plot of inspiratory and expiratory flow (on the Y-axis) against volume (on the X-axis) during the performance of maximally forced inspiratory and expiratory maneuvers.

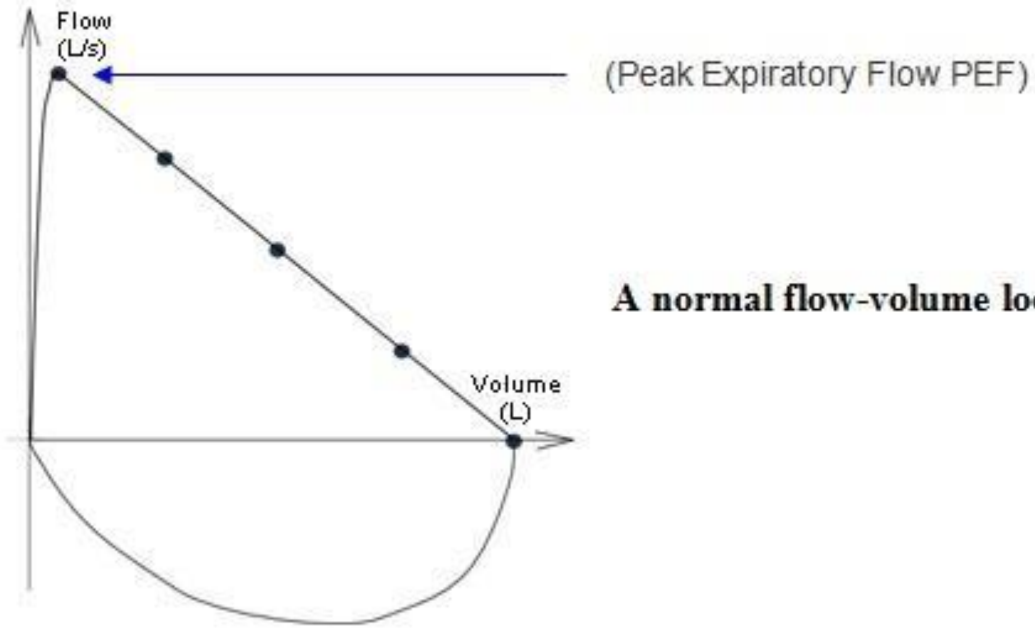
*During EXPIRATION: initial quick peak airflow followed by gradual reduction in flow until it reaches zero.

*INSPIRATORY half of the graph is more symmetrical.

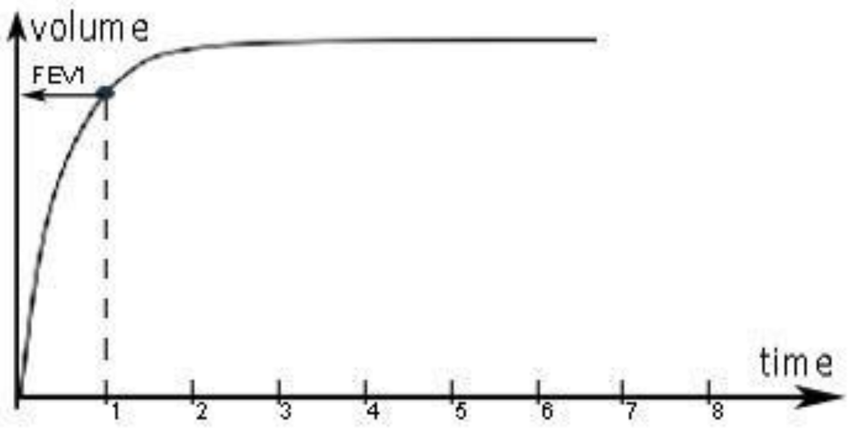
*Shape of the loop can provide important insight of variety of lung diseases.



NORMAL SPIROMETRY

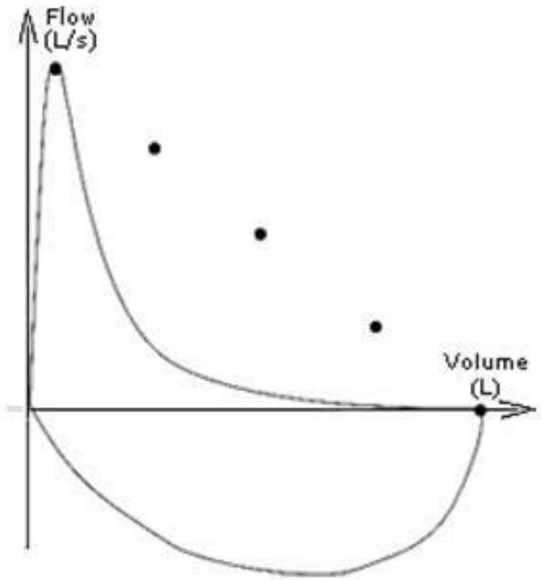


A normal flow-volume loop

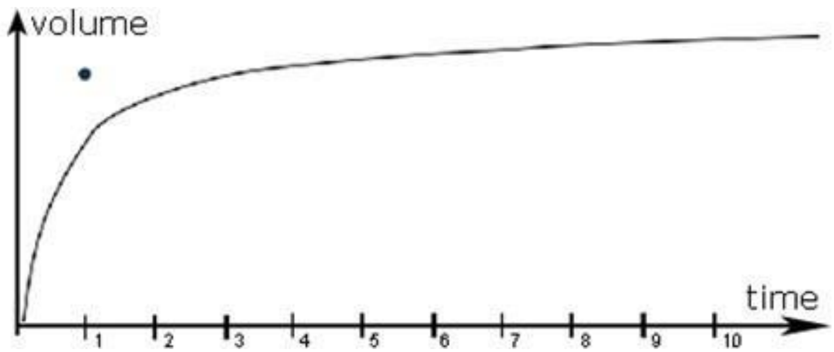


A normal volume-time curve

OBSTRUCTIVE LUNG DISEASE

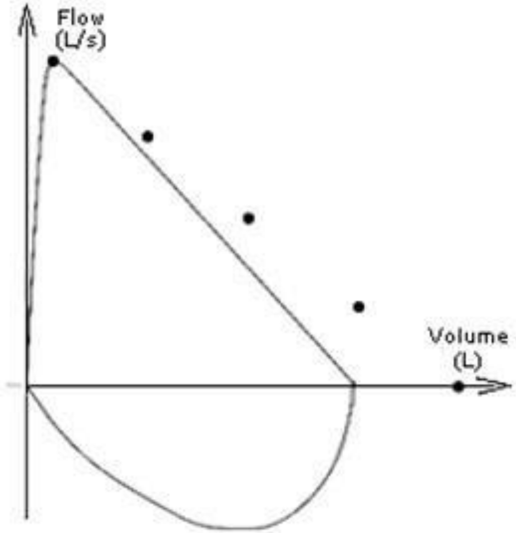


Flow-volume in obstructive lung disease is concave, FEF25-75 too low, FVC normal

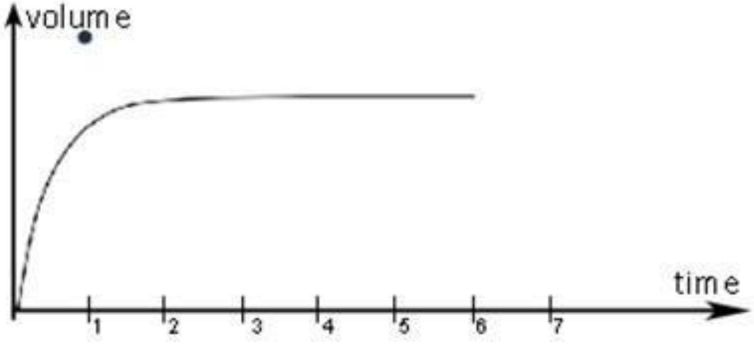


Volume-time curve in obstructive lung disease: FEV1 low, FET higher

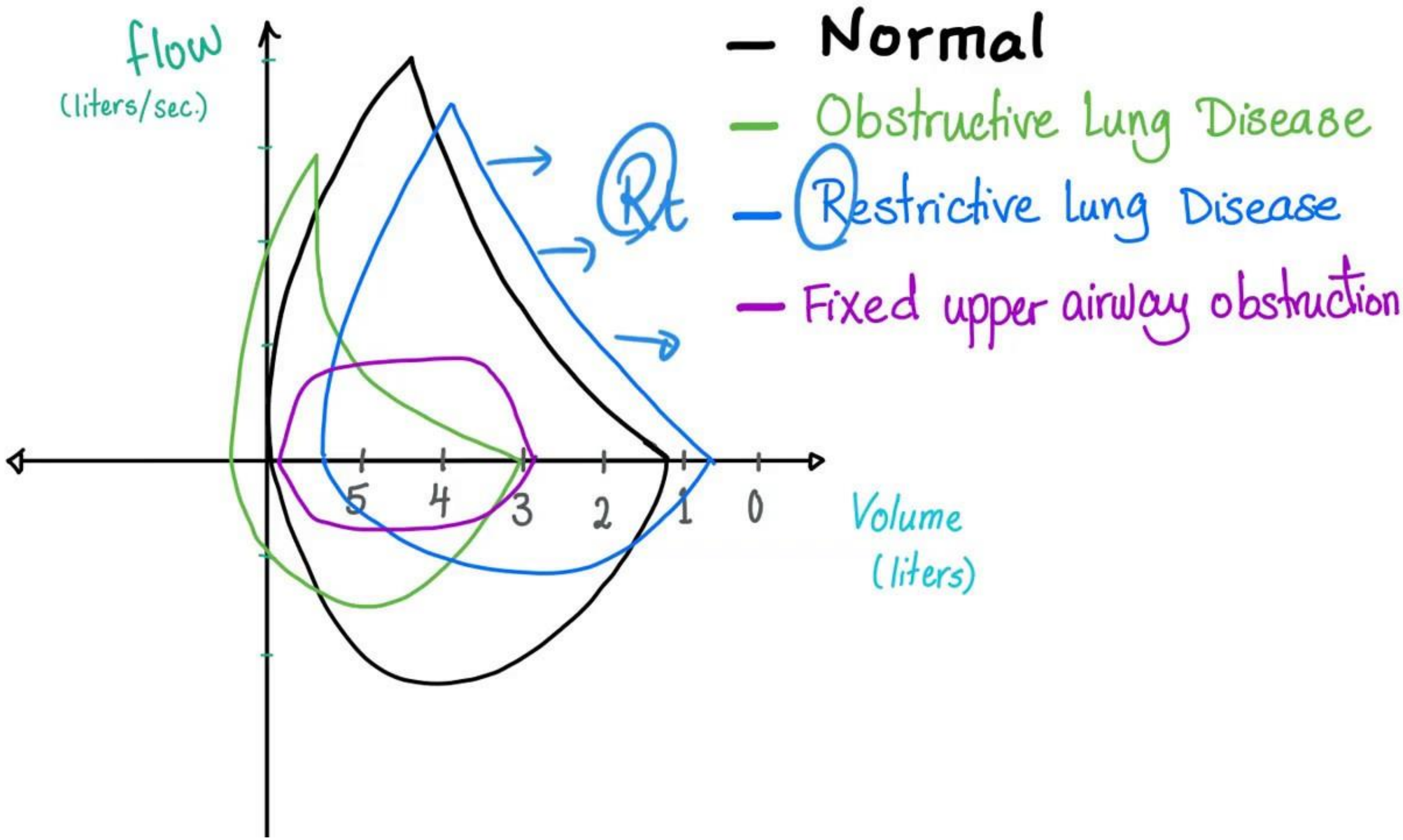
RESTRICTIVE LUNG DISEASE

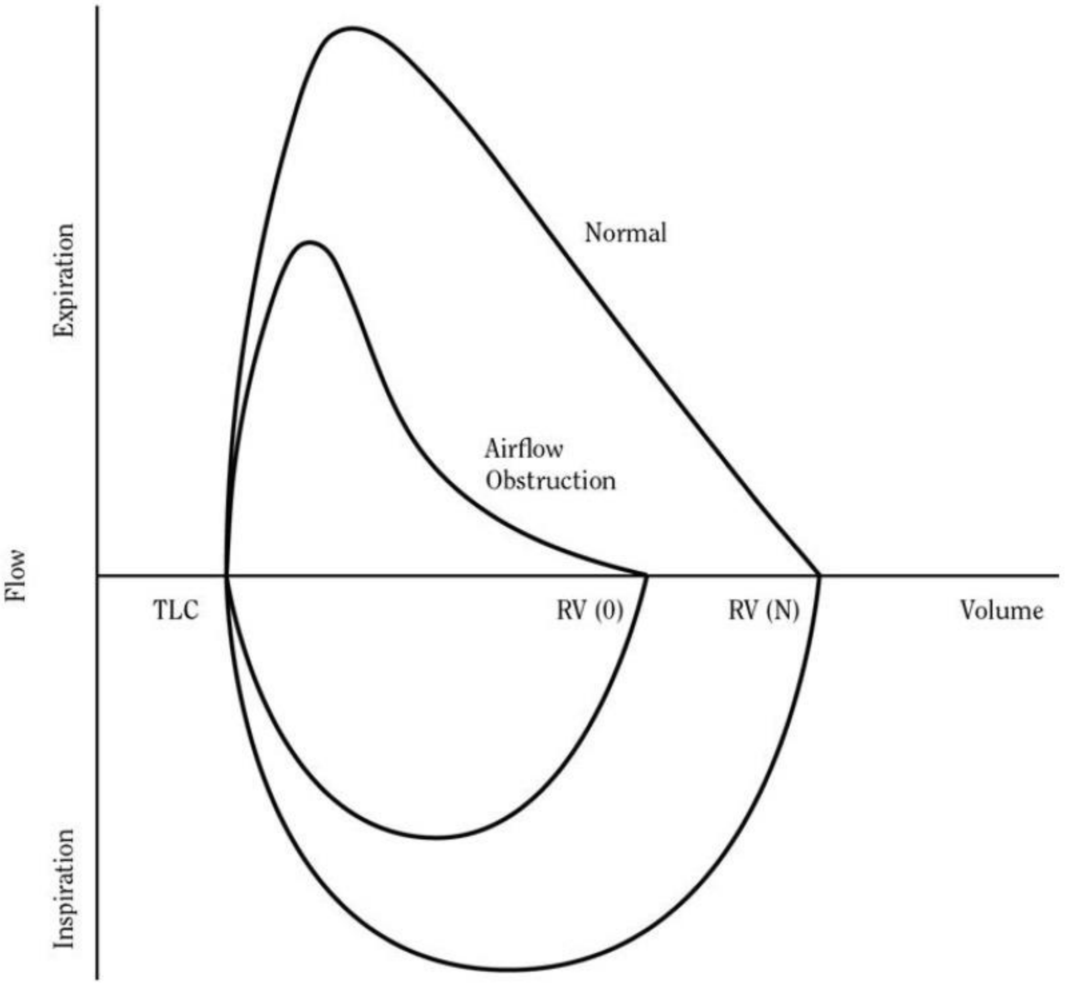


Flow-volume in restrictive lung disease:
shape normal, FVC low. PEF can be normal or low



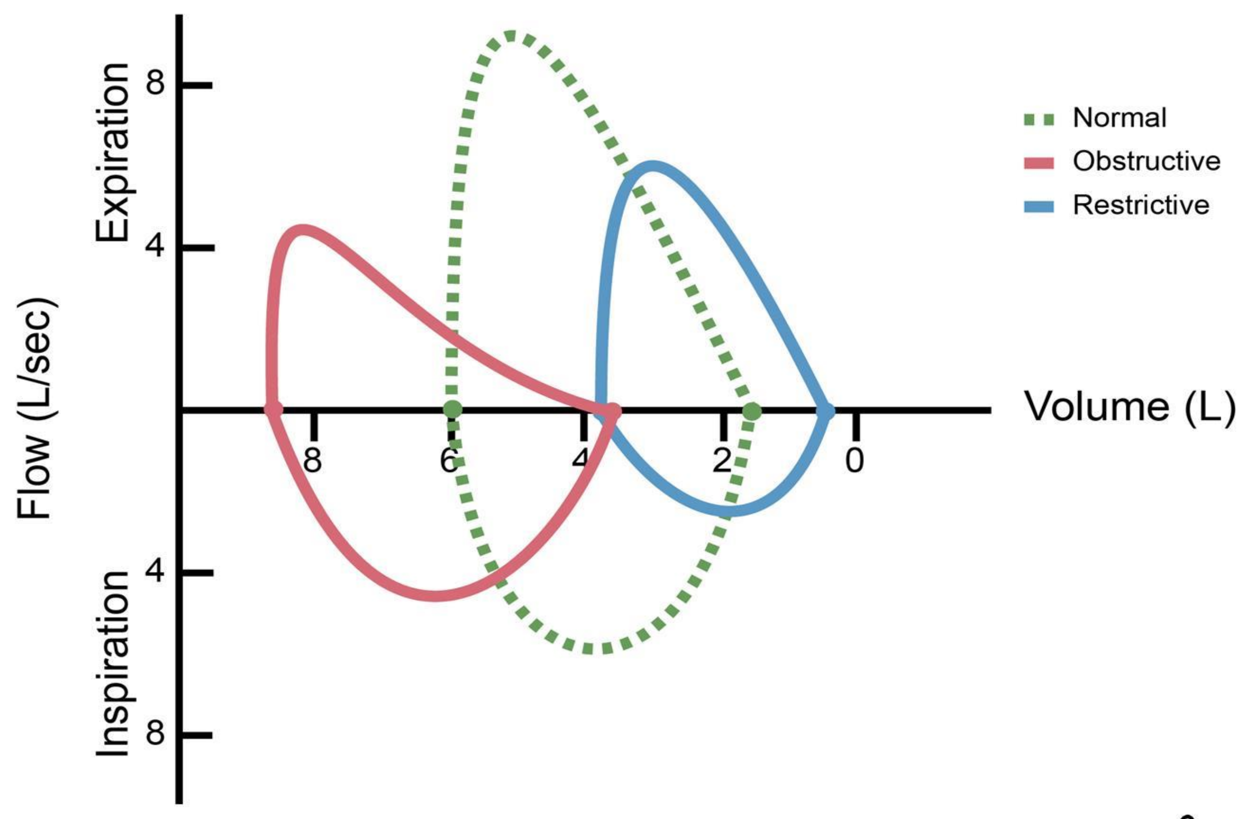
Volume-time curve in restrictive lung disease:
FEV1 too low, FET normal


flow
(liters/sec.)
Volume
(liters)
5
4
3
2
1
0
Rt
Normal
Obstructive Lung Disease
Restrictive lung Disease
Fixed upper airway obstruction



Normal
Airflow
Obstruction
Expiration
Flow
Inspiration
TLC
RV (0)
RV (N)
Volume

Flow Volume Loops

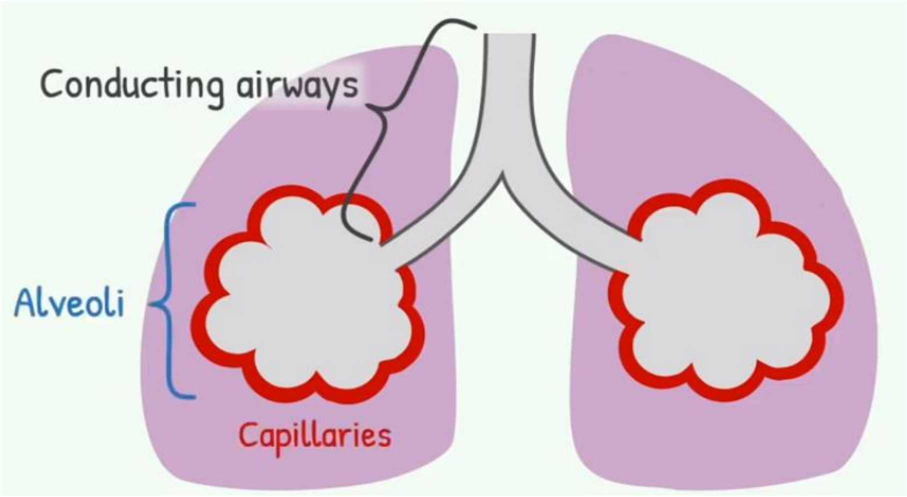


Moises Dominguez

Dead space

1. Anatomical dead space:

- Is the air in the conducting airways that does not engage in gas exchange. It does not include the respiratory bronchioles and alveoli.
- Is normally approximately 150 ml

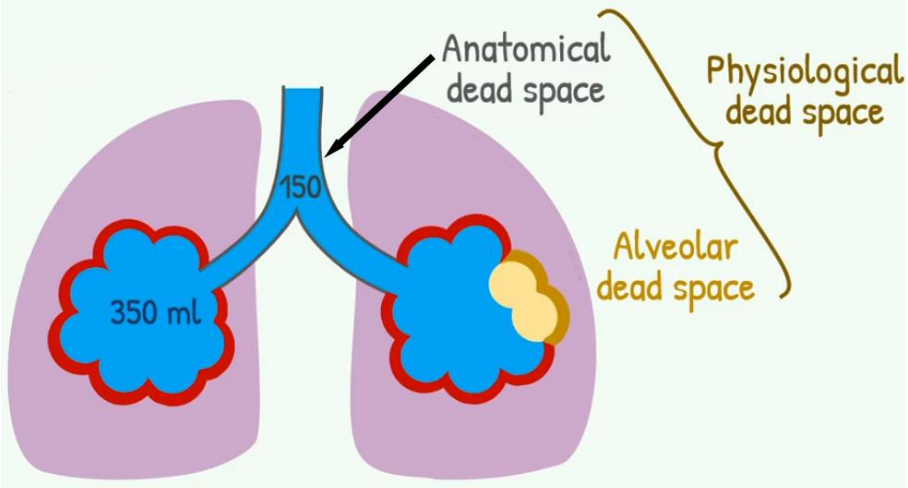


2. Alveolar dead space:

- The air in the alveoli that's surrounded by pulmonary capillaries without blood flow.

3. Physiological dead space:

- Is a functional measurement
- Is the total dead space which is the sum of the anatomic dead space and alveolar dead space.
- May be greater than anatomic dead space in lung diseases in which there are ventilation /perfusion (V/Q) defects



Measurement of physiological dead space

$$V_D = V_T * (P_{ACO_2} - P_{ECO_2}) / P_{ACO_2}$$

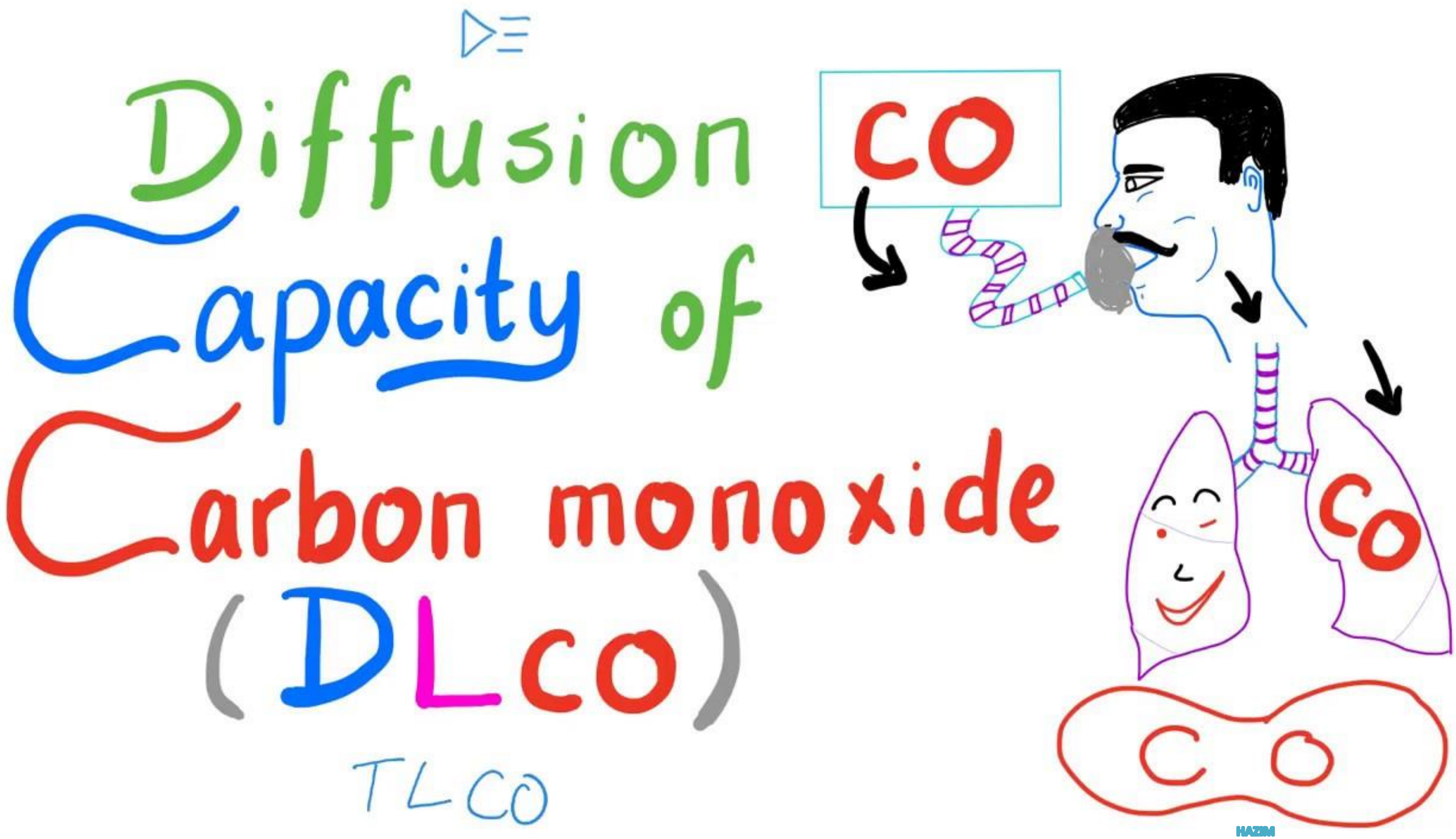
V_D : physiologic dead space

V_T : tidal volume (ml)

P_{ACO_2} : PCO2 of alveolar gas (mm Hg) = **Pco2 of arterial blood**

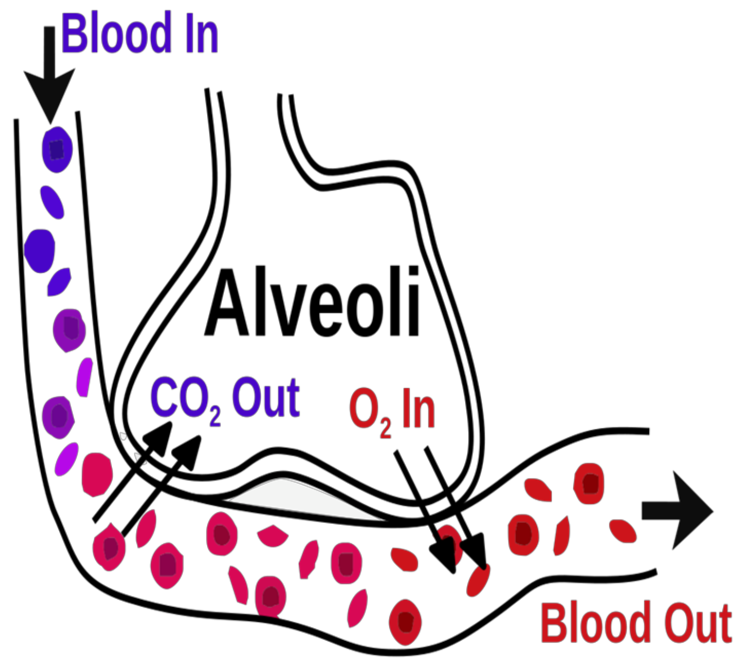
P_{ECO_2} : PCO2 of expired air (mm Hg)

Diffusing Capacity of Carbon Monoxide



DL = Lung Diffusing Capacity

- The measure of overall function of the alveolar-capillary membrane.
- It is the rate at which gas enters the blood.
- DL is measured with carbon monoxide (DLCO).
- Normal/Mean DLCO for healthy adults is 25 (20 -30) ml/min/mmHg.
- Measurement affected by body size, age, lung volume, exercise, body position, and hemoglobin concentration.

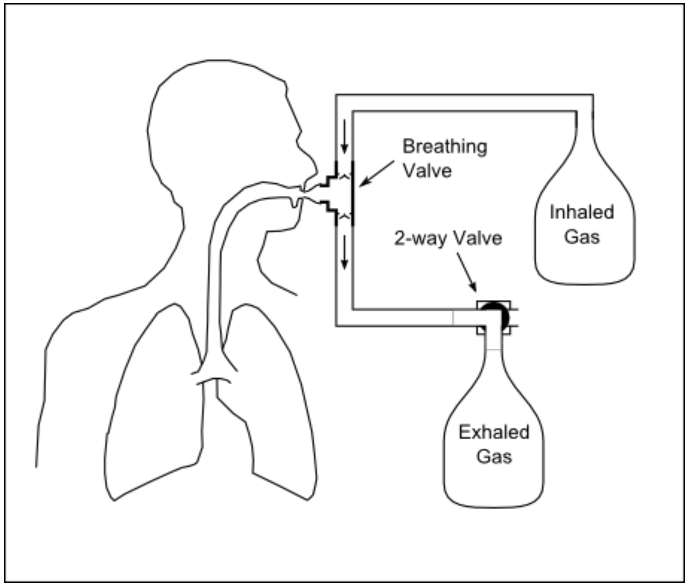


INDICATIONS

- Obstructive disease
- Restrictive disease
- Pulmonary vascular disease
- Prior to lung resection surgery
- Need for oxygen therapy

DLCO Maneuver Single-Breath Technique.

- The patient takes a full inspiration of a gas mixture containing 0.3 percent carbon monoxide and 10 percent helium.
- After a ten-second breath-hold, the patient exhales.
- The first portion of the exhaled breath, which is composed of dead-space ventilation, is discarded, and the next liter is collected and analyzed
- The difference between the original and final concentrations of carbon monoxide is assumed to represent the gas transported across the lung alveolar surface and to reflect the diffusion capacity.



Conditions and Physiologic States that alter DLCO

↑ DLCO:

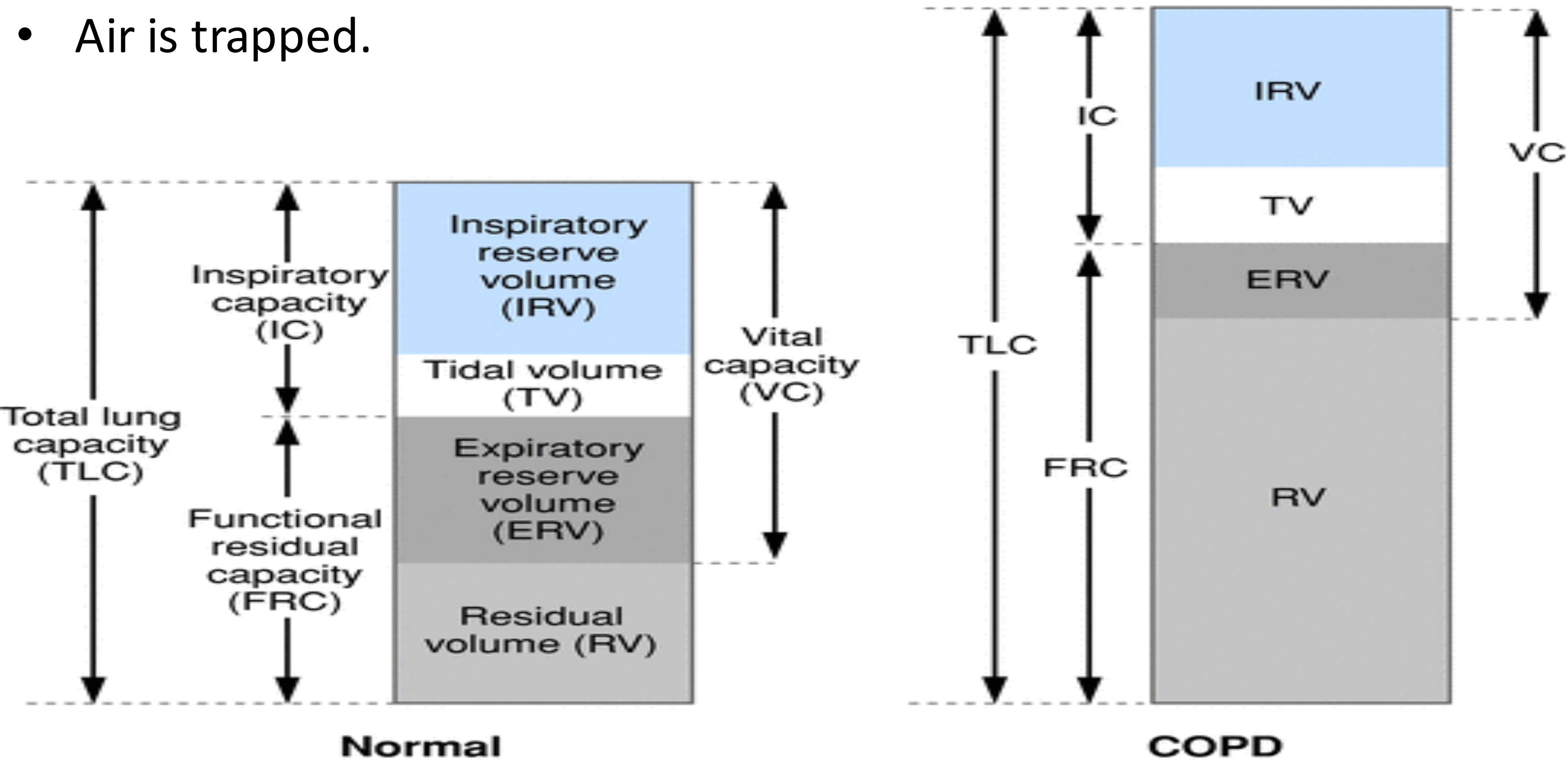
- Exercise, supine position
- Obesity
- Asthma
- Polycythemia

↓ DLCO:

- ↓ Membrane surface area (e.g., emphysema)
- ↑ Membrane thickness (e.g., Pulmonary Fibrosis)
- Pulmonary Hypertension
- Anemia

Obstructive pulmonary disease

- Group of diseases characterized by
- airway obstruction .
- lung does not empty .
- Air is trapped.



Pulmonary compliance :

the ability of the lungs to stretch and expand. Lung compliance can be calculated by dividing volume by pressure.

Factors affecting lung compliance:

1-elasticity from the elastin in connective tissue.

2- surface tension, which is decreased by surfactant production.

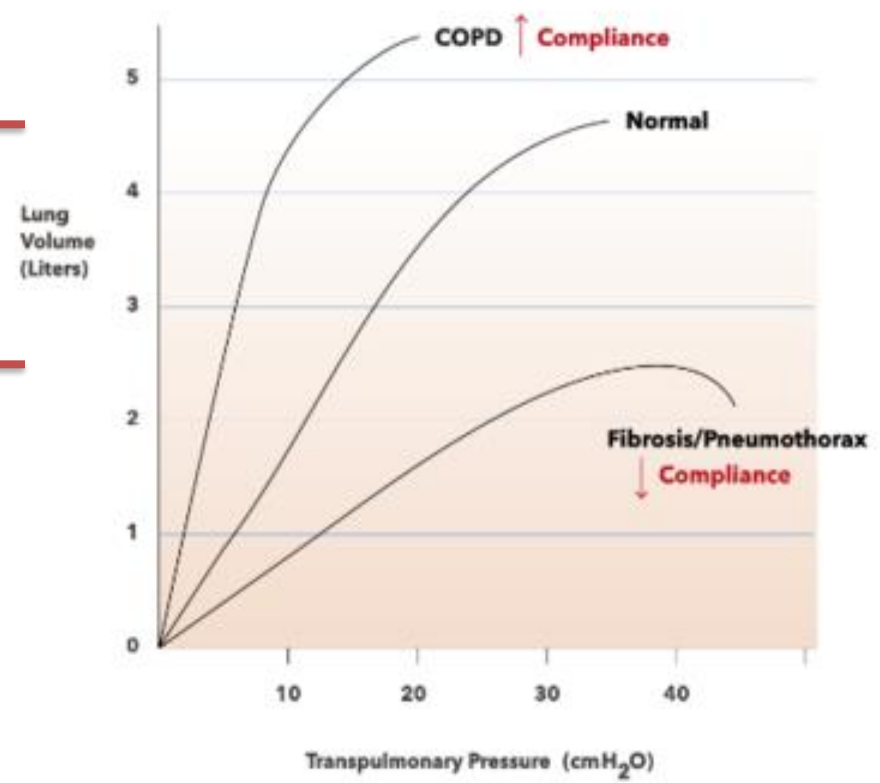
Elastic recoil

the lung's intrinsic tendency to deflate following inflation

- A Increased compliance can indicate obstructive lung diseases
- (recoil decreased)

- A decreased compliance might show restrictive lung diseases.
- (recoil increased)

This chart shows the expiration compliance curves for COPD/chronic obstructive pulmonary disease, normal and Fibrosis/Pneumothorax.



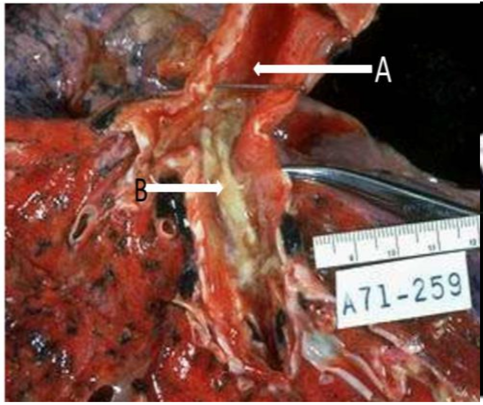
COPD

A)Chronic bronchitis (hypertrophy of bronchial mucosa)

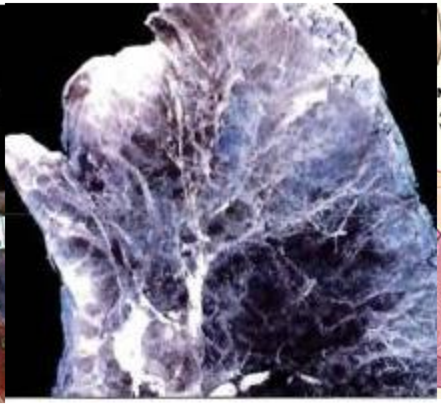
B)emphysema(destruction of alveolar air sac)

C)asthma(reversible bronchoconstriction)

D) bronchiectasis(Permanent dilatation of bronchi ,loss of airway tone)



A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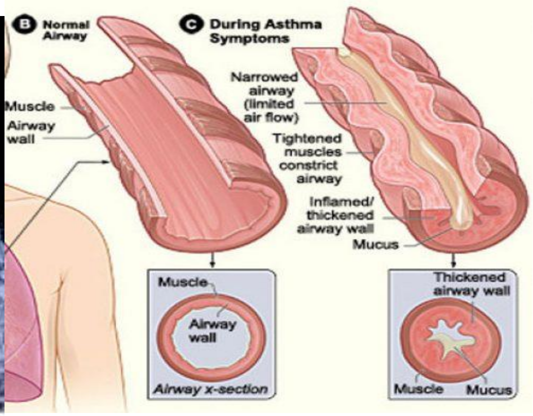

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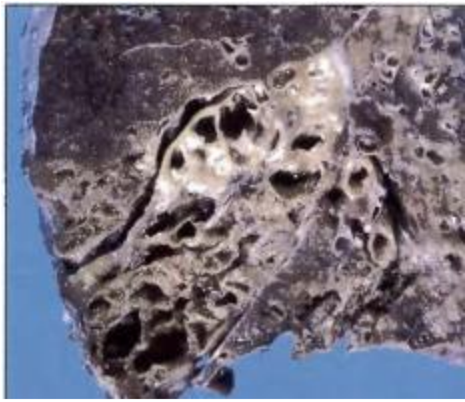
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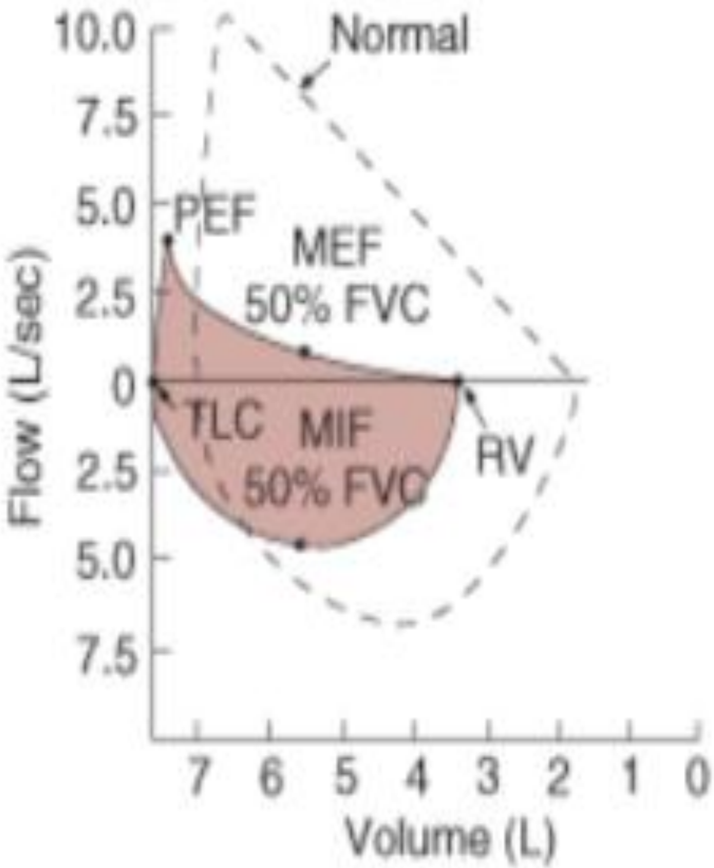
FLOW VOLUME LOOP OF OBSTRUCTIVE PULMONARY DISEASE :



- (↓↓FEV1)
- (↓ PEF)
- (↓FVC)
- ↓FEV1:FVC ratio <80%.
- ↑RV
- ↑TLC
- MIF is greater than MEF

RESTRICTIVE DISEASES

A. Diseases Characterized by restricted filling of the lung;

B. Most commonly due to interstitial diseases of the lung;

may also arise with

-chest wall abnormalities (e.g., massive obesity) ,kyphosis

-Guillain-barre syndrome

-muscular dystrophy(e.g. DMD)

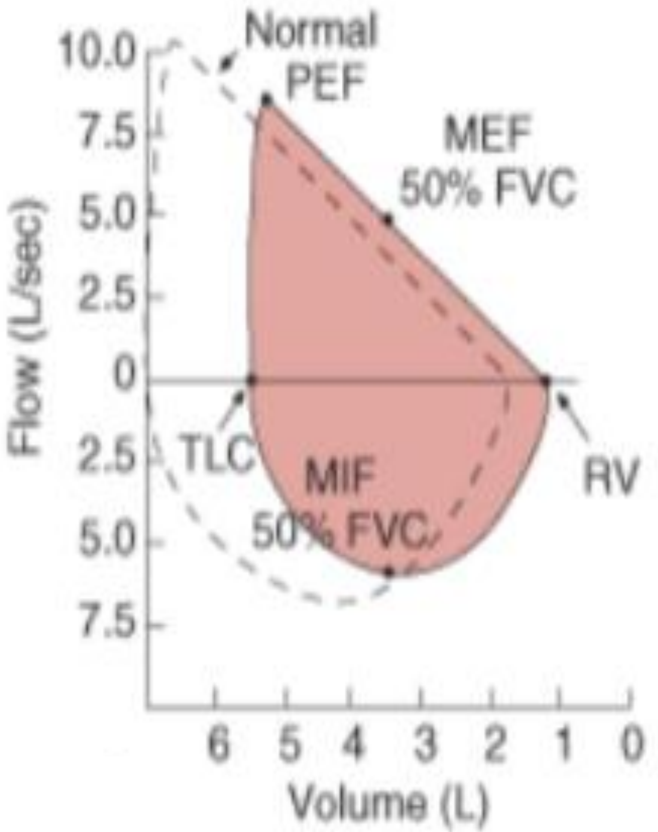
1.The Volume of air that can be forcefully inhaled is decreased leading to (↓FEV1) and (↓ ↓ FVC), results in increase FEV1:FVC ratio >80%.

2. Total lung capacity (TLC) is usually decreased .

RESTRICTIVE PULMONARY DISEASES

1-IDIOPATHIC PULMONARY FIBROSIS.
2- PNEUMOCONIOSES.
3- SARCOIDOSIS .
4-LUNG CANCER.
5-TB.
6-FIBROSIS DUE TO RADIATION.

Flow volume loop of restrictive lung disease



- ↓FEV1
- ,↓↓FVC;
- FEV1:FVC ratio is increased
- ↓ RV
- ↓ TLC
- MIF =MEF

	CHRONIC BRONCHITIS	EMPHYSEMA	Idiopathic lung fibrosis	sarcoidosis
PEF	Decreased	Decreased	decreased	decreased
FEV1/FVC	Decreased	Decreased	Increased	Increased
DLCO	Normal or minimal decreased	Decreased<20 ml/min/mmHg	decreased	decreased
TLC	Increased	Increased	decreased	decreased

Done by

Taha obaid

Mostafa Awwad

Ayman Barham

Abdullah Reqib

Hazem Al-Kousheh

Fadl Tayseer