

# Pulmonary Function Testing

## Chapter 8

# Pulmonary Function Testing

Which of the following is the true pulmonary function test?

- Spirometry
- Lung volumes
- Diffusion capacity
- ABG

# Pulmonary Function Testing

- Process of having the patient perform specific inspiratory and expiratory maneuvers
- Important to be familiar with these tests and values even if you do not work in a PFT lab
- Used for the following:
  - Medical diagnosis
  - Surgery related evaluation
  - Disability evaluation
  - Public Health/Research
  - Studying the effects of exercise on the lungs

# Contraindications

- Recent abdominal, thoracic, or eye surgery
- Hemodynamic instability
- Symptoms of acute severe illness
  - Chest pain, nausea, vomiting, high fever, dyspnea
- Recent hemoptysis
- Pneumothorax
- Recent history of abdominal, thoracic, or cerebral aneurysm

# Normal Values

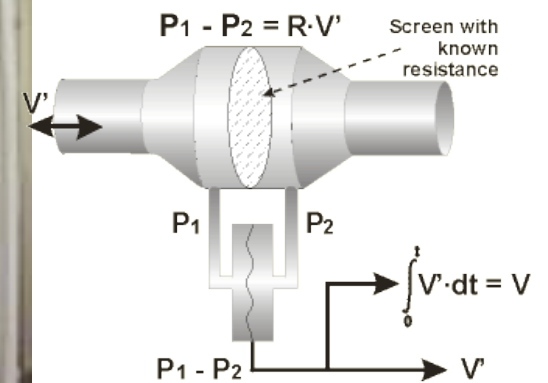
- Height
- Weight
- Age
- Gender
- Race
- Effort dependent

# Patient Instructions Prior to Testing

- Should not drink alcohol for four hours prior to test
- Should not smoke at least one hour before test
- Do not eat a large meal two hours prior to test
- No vigorous exercise 30 minutes before test
- Do not wear tight form fitting clothes
- May need to remove loose dentures for test
- Should wait at least one month post MI, consider impact of problems that may affect results (chest/abdominal pain, oral or facial pain, stress incontinence, dementia, physical deformities or medical conditions)
- Bring a list of all medications – potentially withhold bronchodilators, corticosteroids

# Equipment

- Spirometer
- Respirometer
- Pneumotachometer
- Body Plethysmograph - body box
- Diffusion System
- Gas Analysis



# ATPS vs BTPS

- Ambient Temperature and Pressure Saturated
- Ambient temp is less than body temp
- Volume of air measured by spirometer is slightly less than the volume actually exhaled
- Measurements made by system must be converted
- Body Temperature and Pressure Saturated
- Requires knowing the ambient temperature, barometric pressure and humidity level
- ATPS is multiplied by the correction factor to obtain the higher BTPS values



# Conversion from ATPS to BTPS conditions

Temp.°C	Corr.factor						
16	1.123	21	1.097	26	1.069	31	1.039
17	1.118	22	1.091	27	1.063	32	1.033
18	1.113	23	1.086	28	1.057	33	1.026
19	1.107	24	1.080	29	1.051	34	1.020
20	1.102	25	1.074	30	1.045	35	1.013

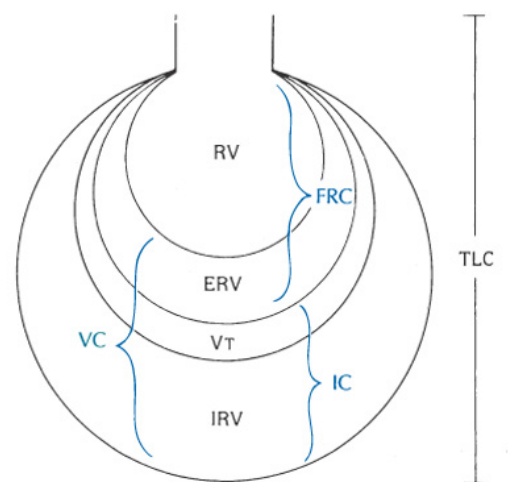
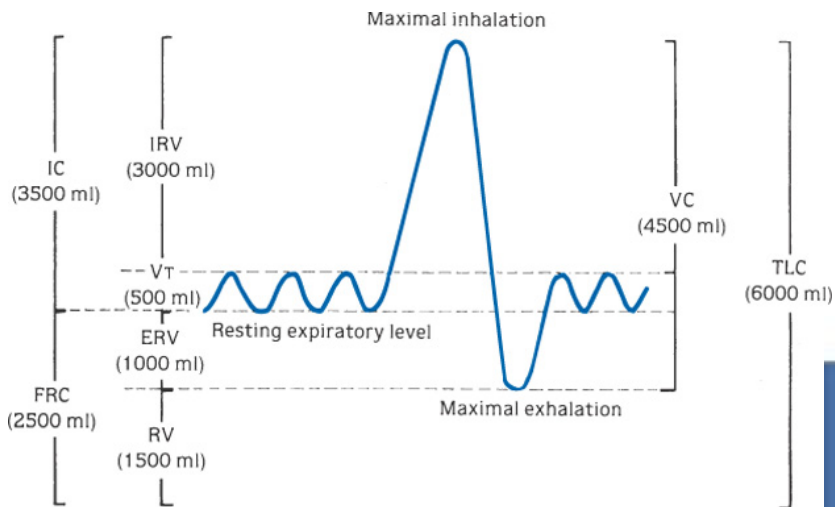
# Classification of Lung Defects

## OBSTRUCTIVE

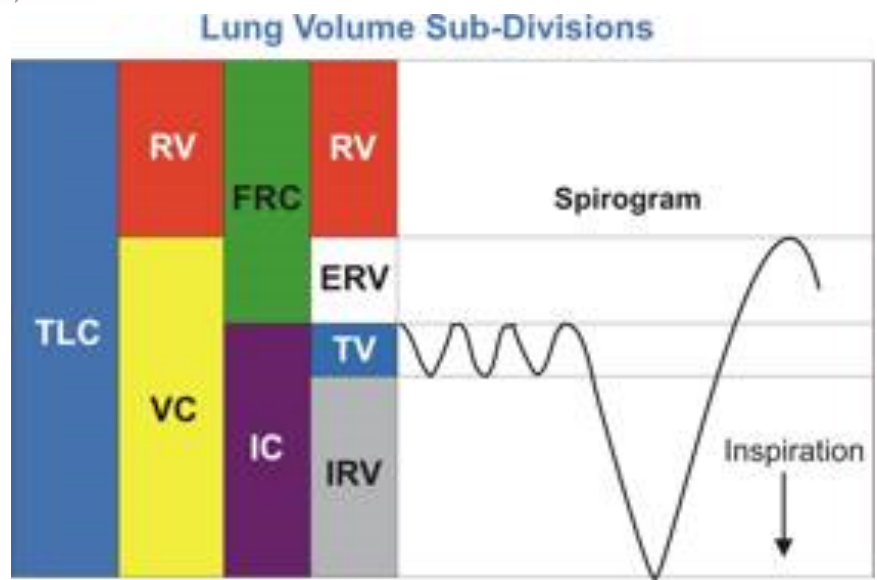
- Expiratory flow is below normal
- Anatomic site can be identified
- Diseases:
  - Cystic fibrosis
  - Bronchitis
  - Asthma
  - Bronchiectasis
  - Emphysema

## RESTRICTIVE

- Lung volumes are reduced
- Diseases:
  - Neuromuscular
  - Cardiovascular
  - Pulmonary
  - Trauma/chest wall dysfunction
  - Obesity



(From Scanlan CL, Spearman CB, Sheldon RL: *Egan's fundamentals of respiratory care*, ed 5, St Louis, 1990, Mosby.)



# NORMAL SPIROGRAM

# Spirogram

## **Volumes**

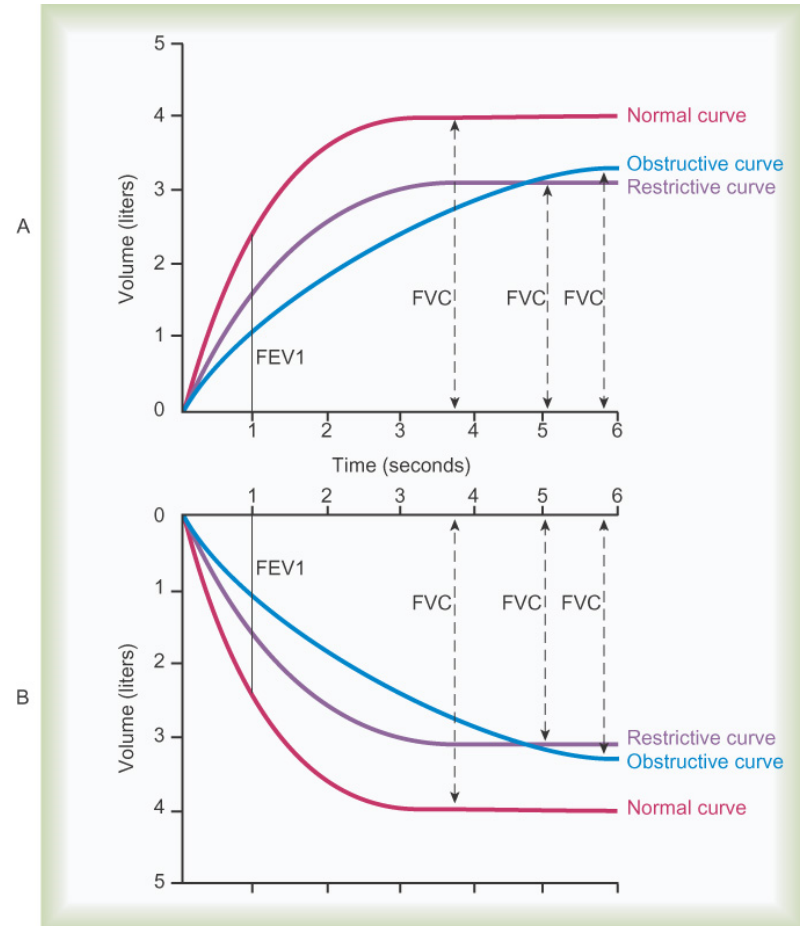
- Tidal Volume
- Minute Volume
- Residual Volume
- Inspiratory Reserve Volume
- Expiratory Reserve Volume

## **Capacities**

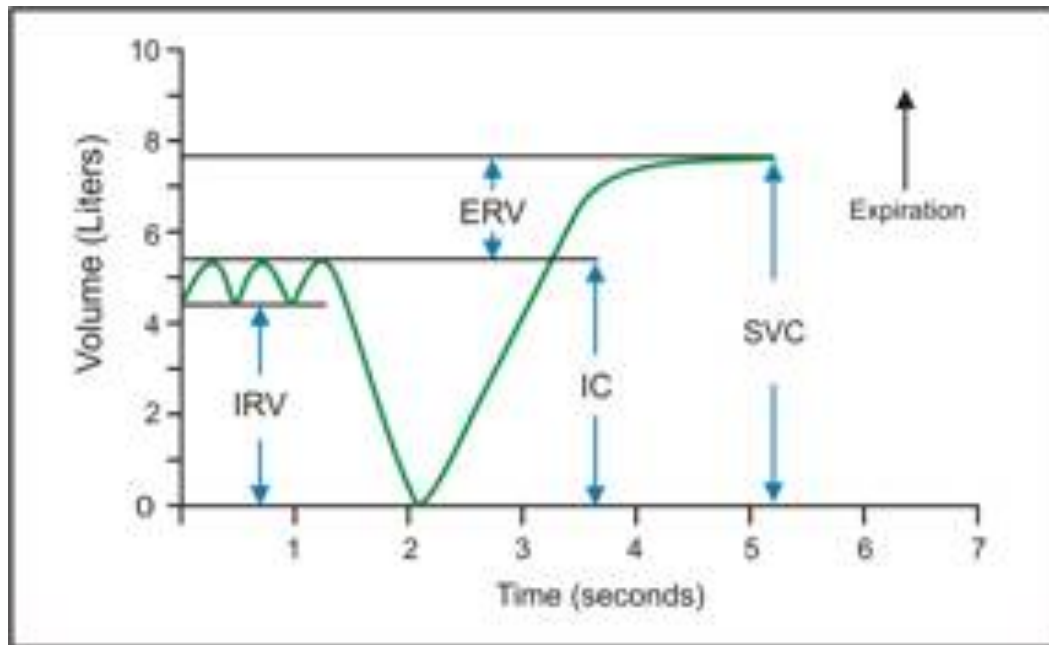
- Vital Capacity
- Total Lung Capacity
- Function Residual Capacity
- Inspiratory Capacity

# Vital Capacity

- Forced (FVC)
  - Requires proper coaching
  - Three distinct phases
  - Decreased in both obstructive and restrictive diseases
- Slow (SVC)
  - Helps avoid air trapping



# Slow Vital Capacity



# Total Lung Capacity

- Increased with obstructive disease
- Decreased with restrictive disorders
- Sum of the vital capacity and residual volume
- Obtain RV by:
  - Body plethysmography
  - Nitrogen washout
  - Helium dilution

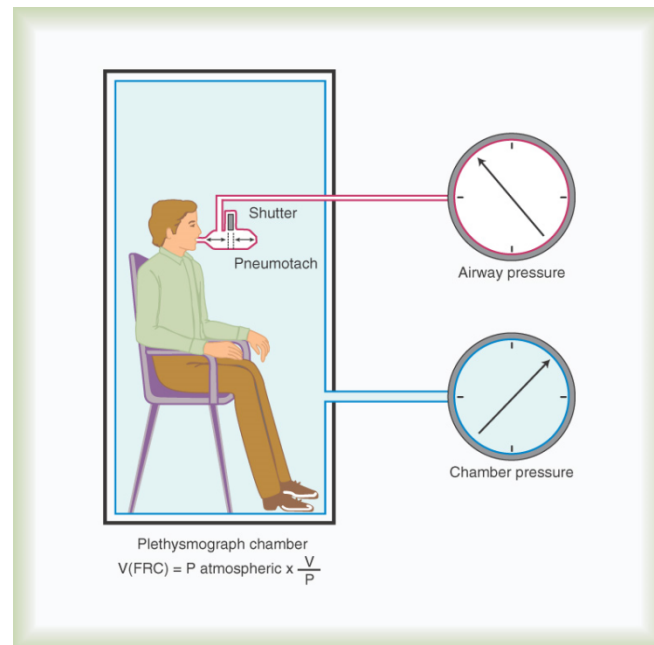
# Body Plethysmography

- Uses the “body box”
- Boyles Law

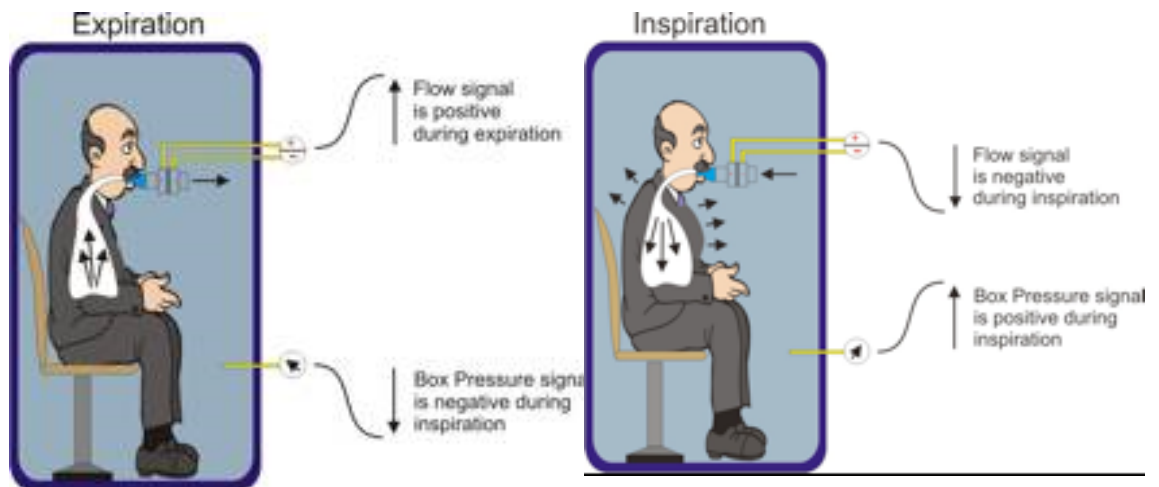
Unknown lung gas vol = Gas pressure of the box

Known box gas vol

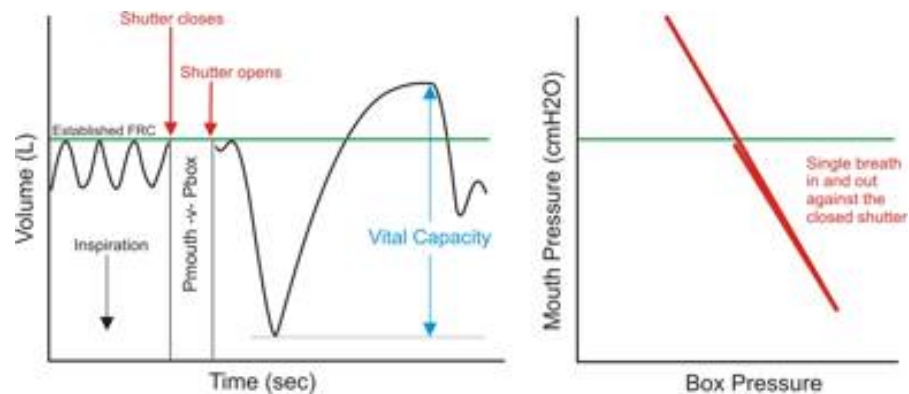
Gas pressure of the lungs





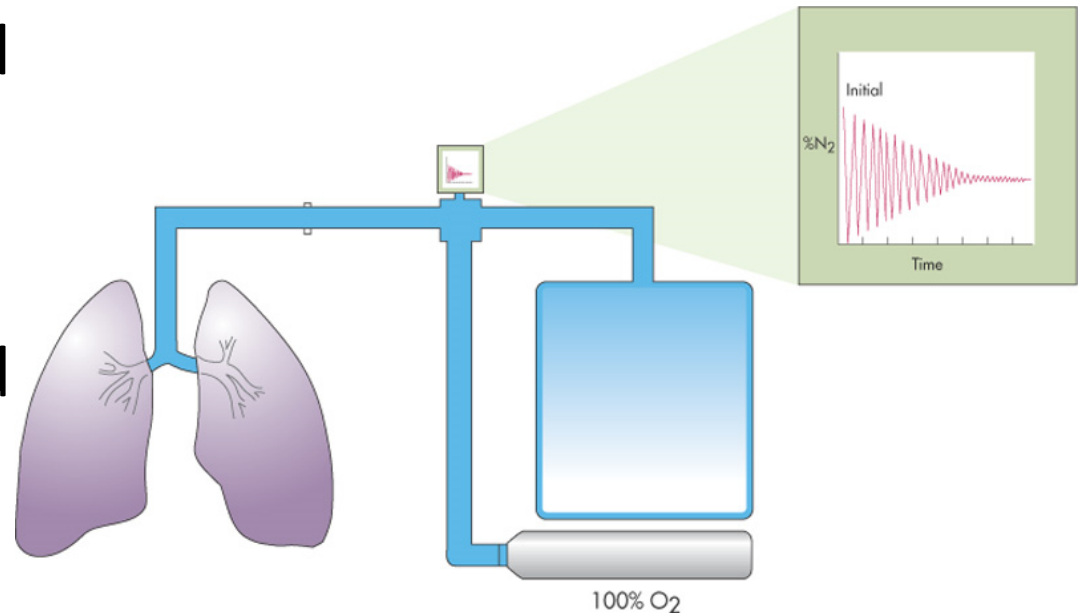


In body plethysmography, the patient sits inside an airtight box, inhales or exhales to a particular volume (usually FRC), and then a shutter drops across their breathing valve. The subject makes respiratory efforts against the closed shutter causing their chest volume to expand and decompressing the air in their lungs. The increase in their chest volume slightly reduces the box volume and thus increases the pressure in the box. This method of measuring FRC actually measures all the conducting pathways including abdominal gas; the actual measurement made is VTG (Volume of Thoracic gas).



# Nitrogen Washout

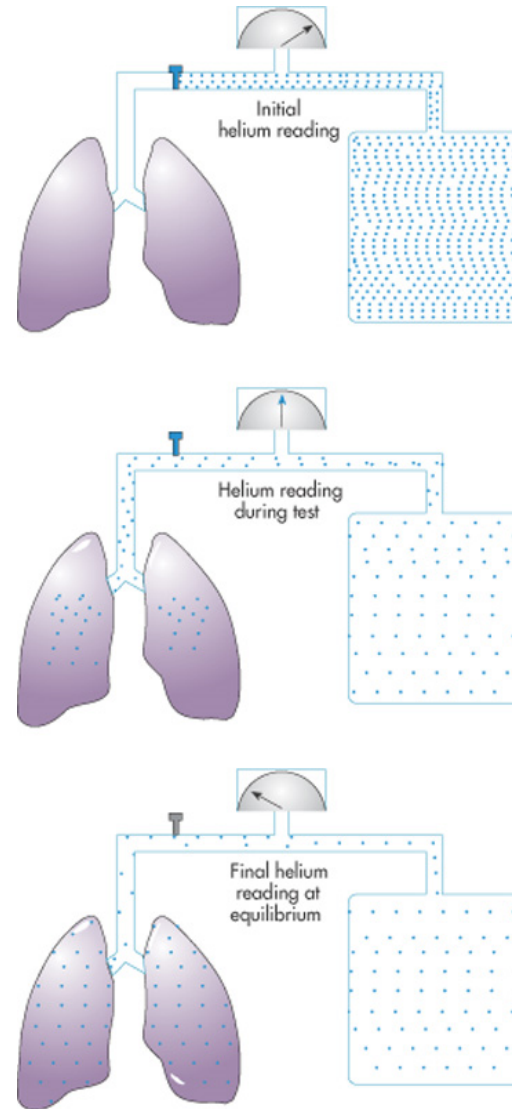
- Open circuit method
- Patient breathes 100% oxygen while the nitrogen washed out of the lungs is measured
- Assumes 79% of lung volume is nitrogen
- Several “problems” with this test



(From Wilkins RL, Stoller JK, Scanlan CL: *Egan's fundamentals of respiratory care*, ed 8, St Louis, 2003, Mosby.)

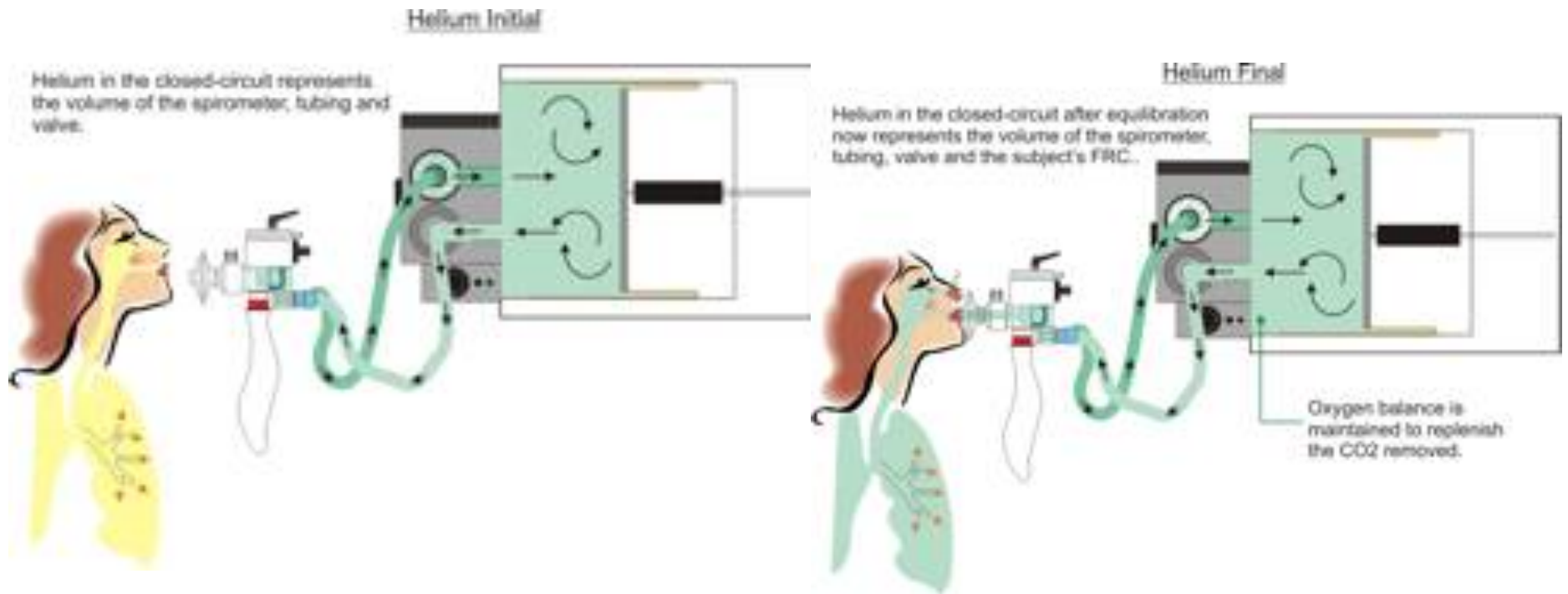
# Helium Dilution

- Closed system
- Known volume and concentration of He added and it will be diluted in proportion to the size of the lung volume

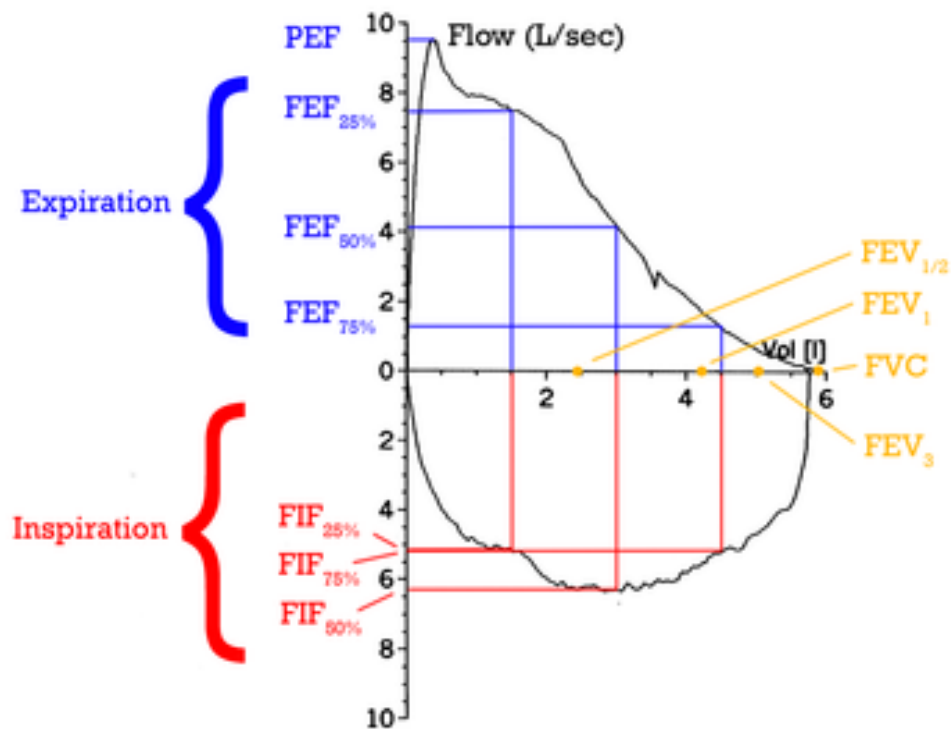


(From Wilkins RL, Stoller JK, Scanlan CL: *Egan's fundamentals of respiratory care*, ed 8, St Louis, 2003, Mosby)

# Helium Dilution



# Flow Measurements



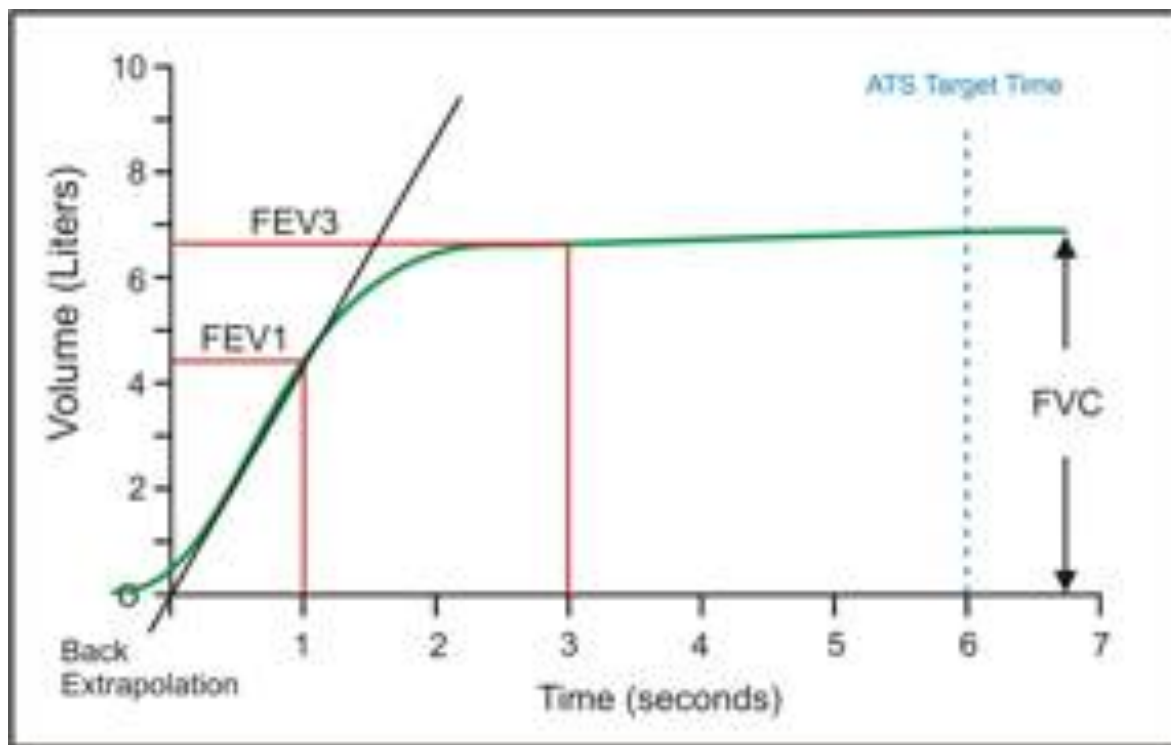
- FEV<sub>1</sub>
- FEV<sub>3</sub>
- FEF<sub>200-1200</sub> FEF<sub>25-75%</sub>
- PEFR

# FEV<sub>1</sub>

- Maximal volume exhaled during the first second of expiration
- Best indicator of obstructive lung disease
- Flow characteristics of the larger airways
- Best expressed as a percentage of the FVC (FEV<sub>1</sub>/FVC)
  - Should be able to exhale 70% of the vital capacity in the first second
  - Decreased in obstructive disorders

# FEV<sub>3</sub>

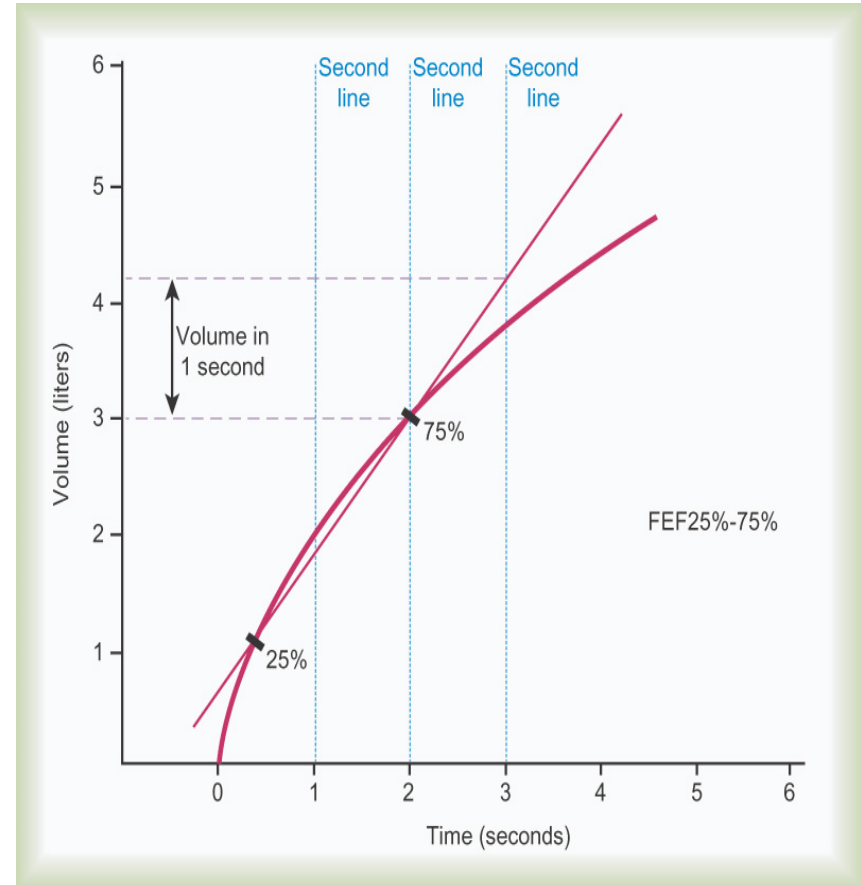
- Evaluates flow 3 seconds into expiration
- Indicates flow in the smaller airways



# Forced Expiratory Flow

## FEF 25-75%

- Examines the middle 50% of the exhaled curve
- Reflects degree of airway patency/condition of the medium to small airways
- Early indicator of obstructive dysfunction
- Normal value is 4-5 L/sec

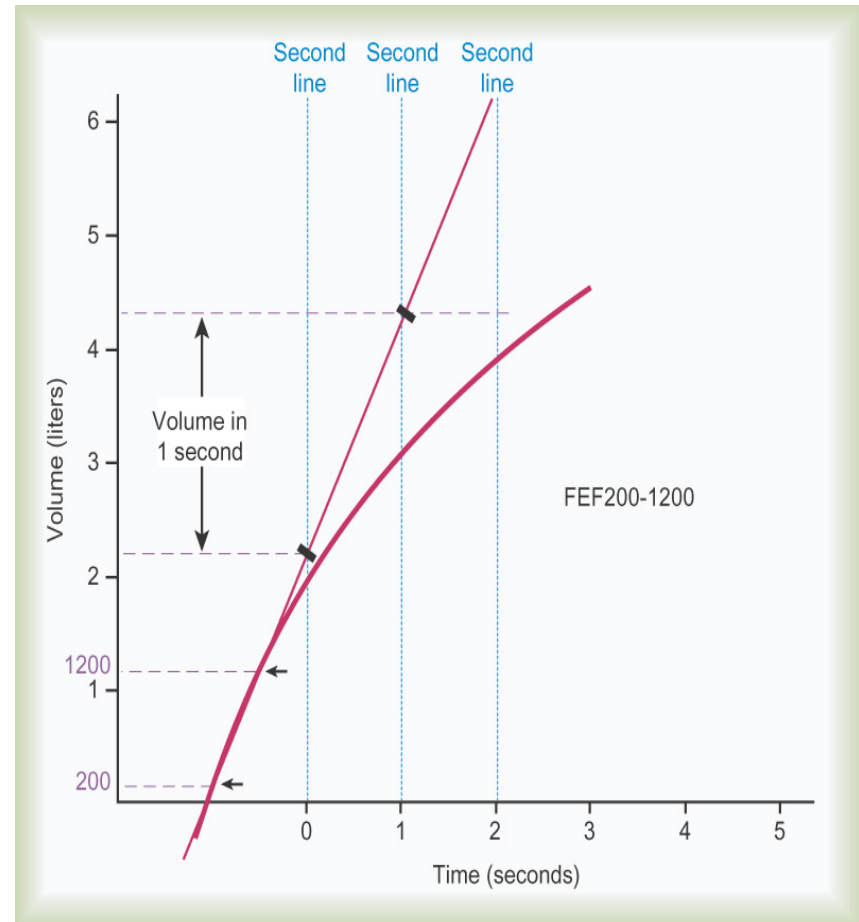




# Forced Expiratory Flow

## FEF 200-1200

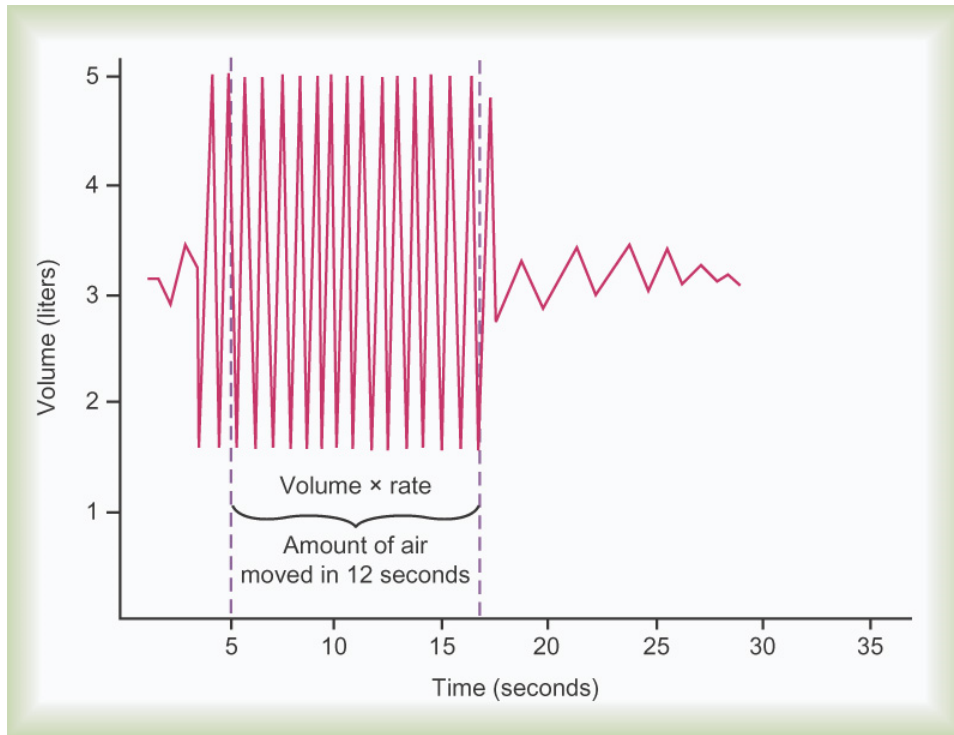
- Average flow after the first 200ml is exhaled
- Good indicator of the integrity of large airway functioning
- Decreased in obstructive disorders
- Normal value is 6-7L/se



# Peak Expiratory Flow Rate

- Maximum flow rate achieved during an FVC
- Used in asthmatics to identify the severity of airway obstruction and guide therapy
- Dependent on patient effort
- Normal value is 10L/sec (600L/min), decreases with age and obstruction

# Maximum Voluntary Ventilation

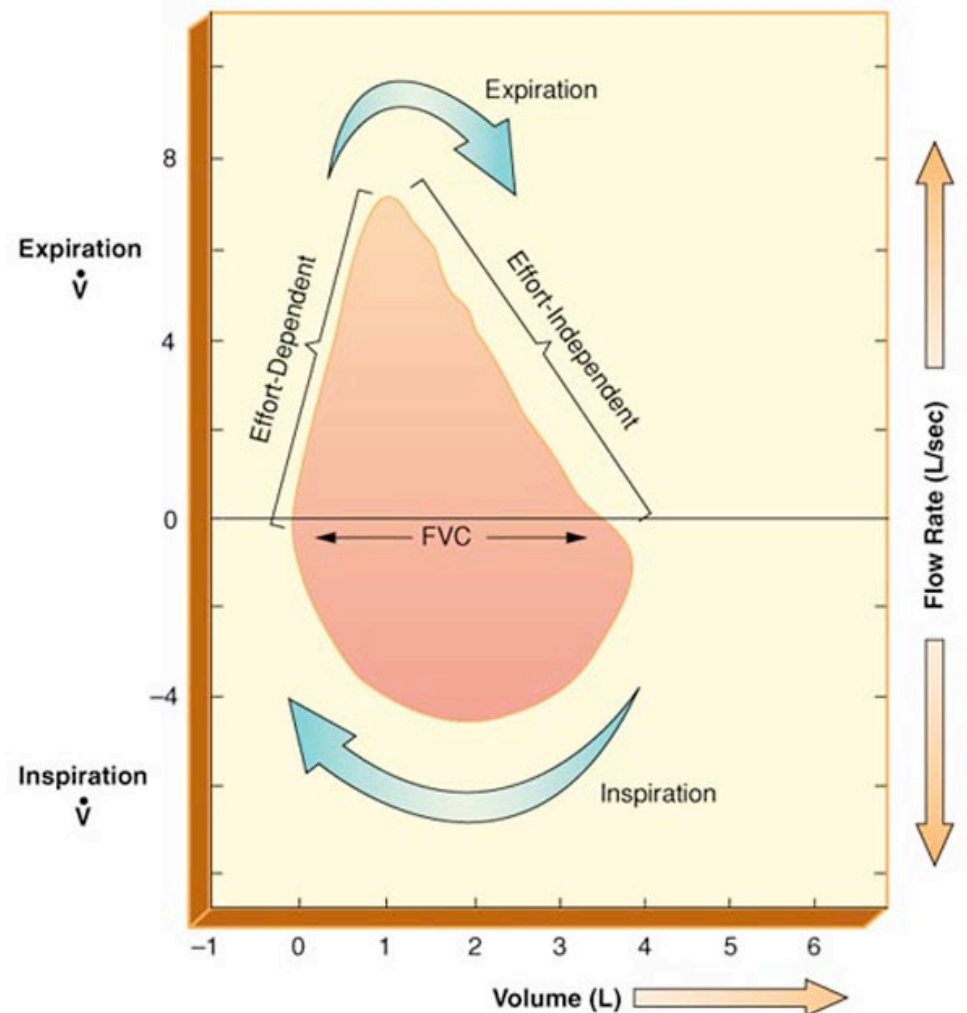


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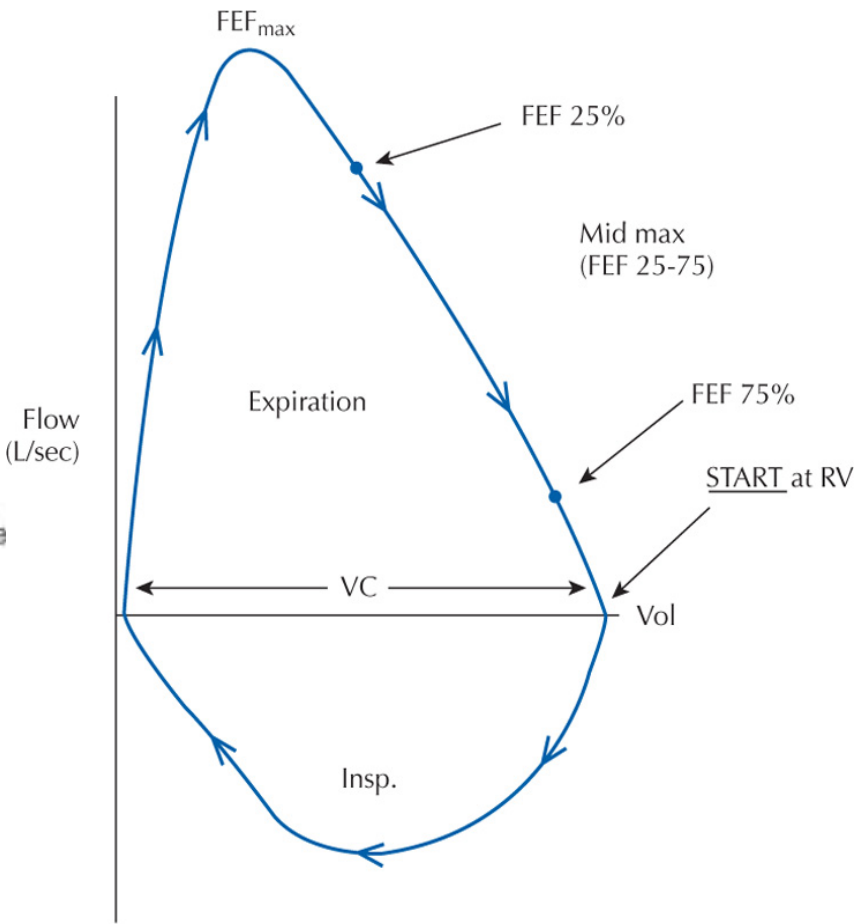
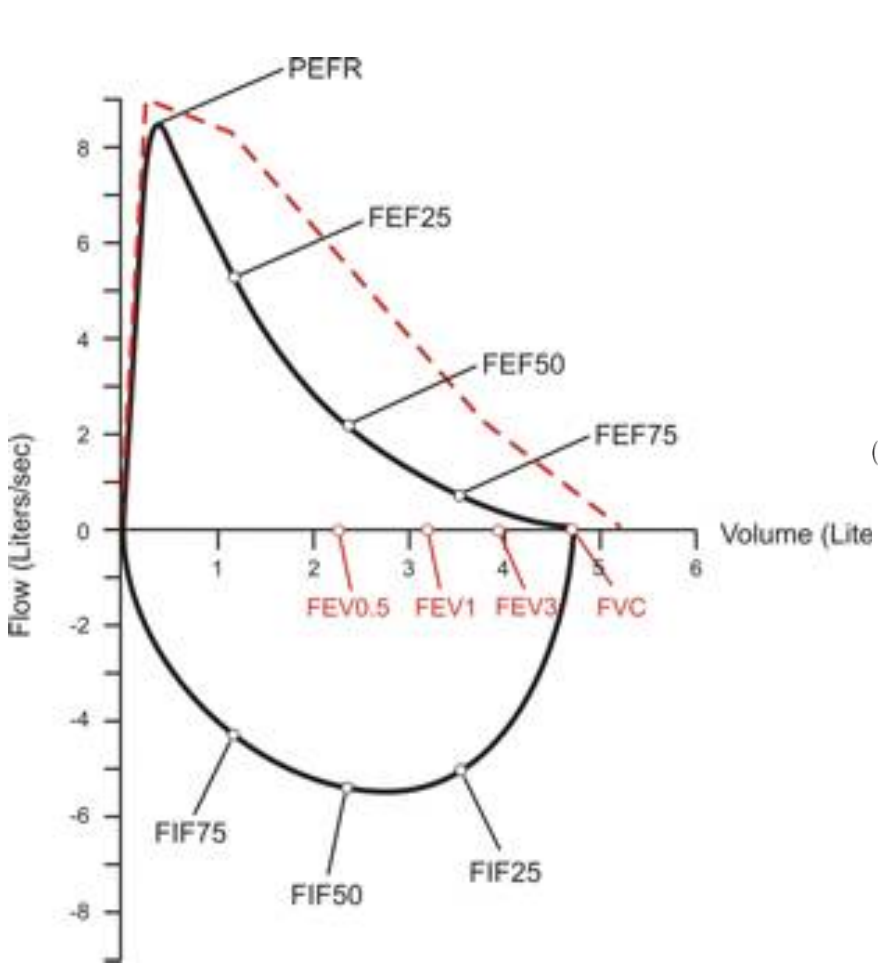
- MVV – patient breathes as fast and deep as possible for 12-15 seconds
- Tests for overall lung function, ventilatory reserve capacity and air trapping
- Normal = 170L/min
- Decreased in obstructive disorders

# Flow Volume Loops

- Identify inspiratory and expiratory components – opposite from ventilator waveforms!
- Reveals a pattern typical for certain diseases



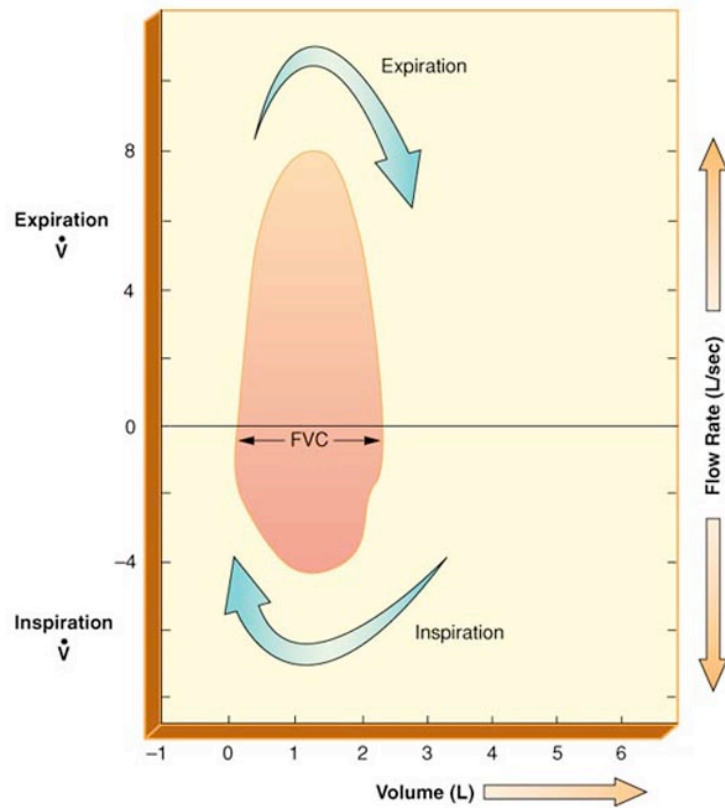
# Graphic Representation of Values



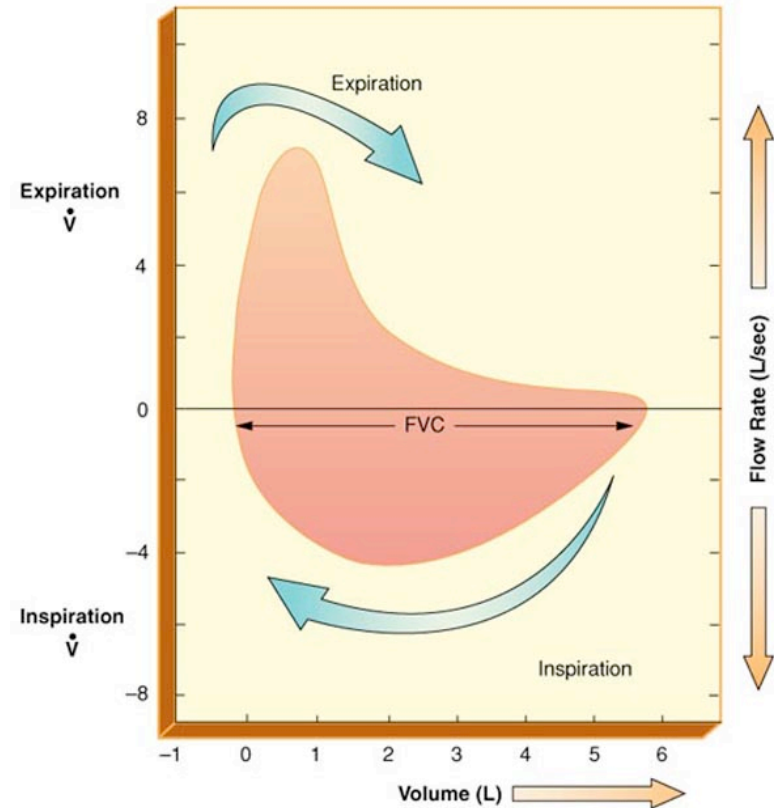
A. Normal curve  
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# Flow Volume Loops

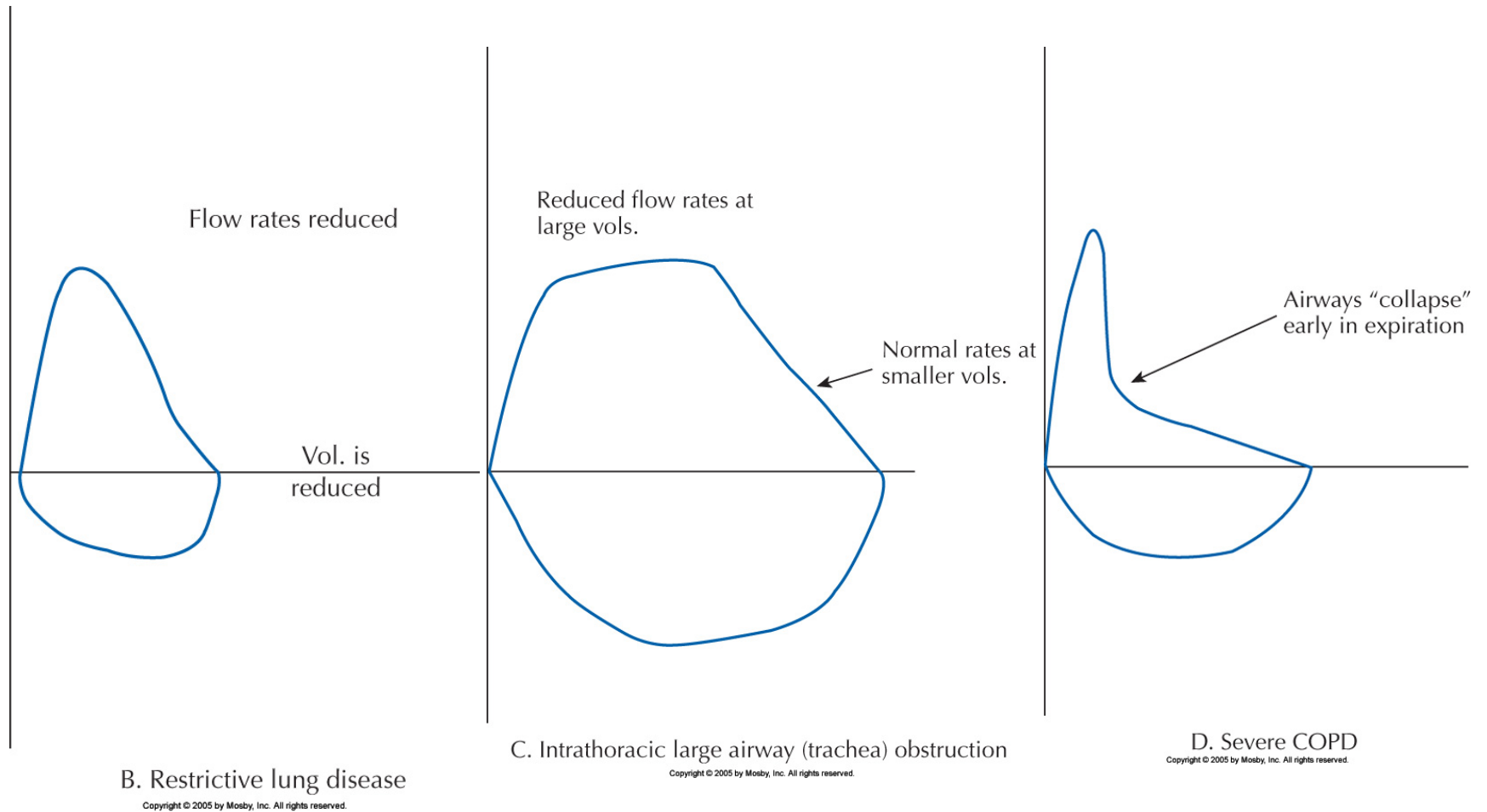
## Restrictive

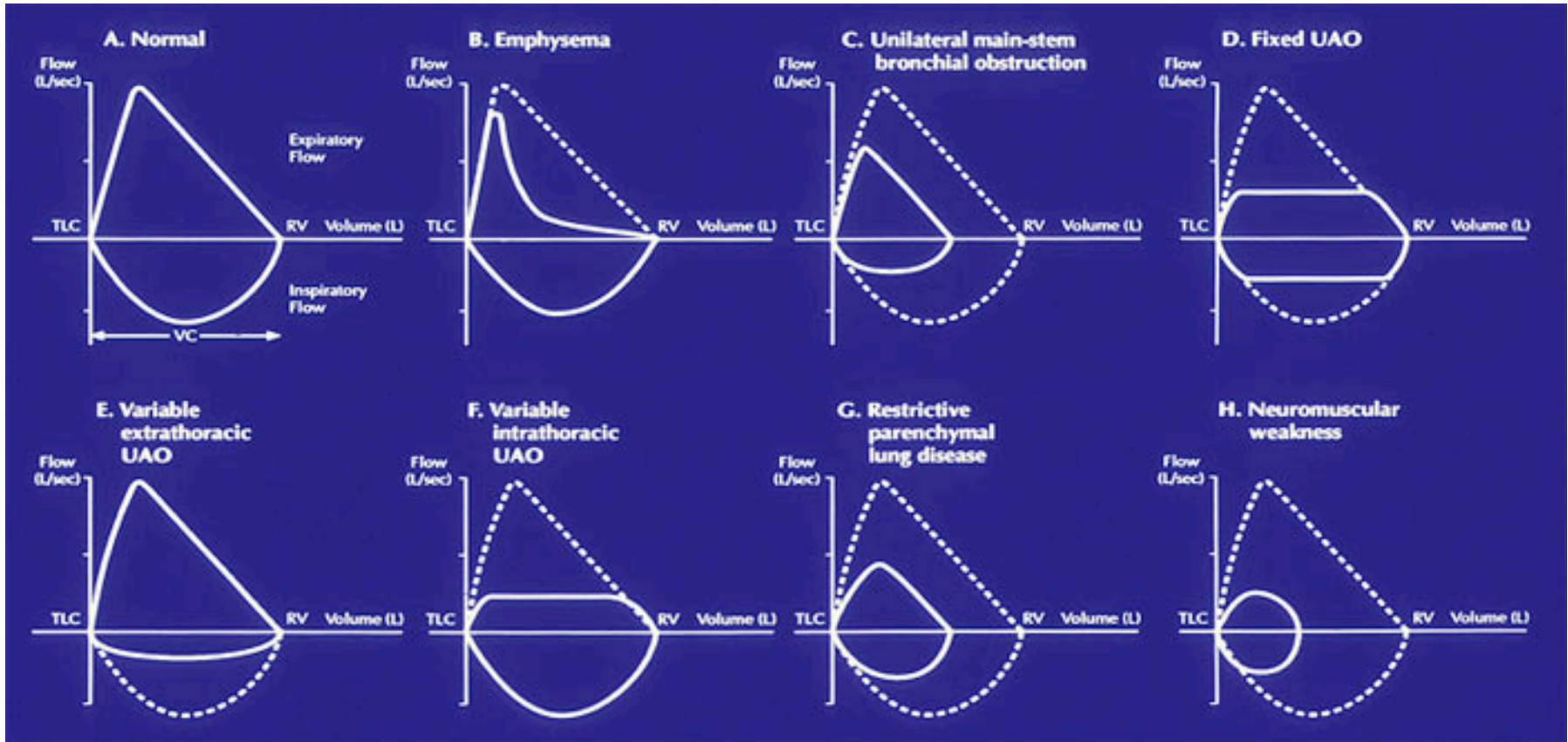


## Obstructive



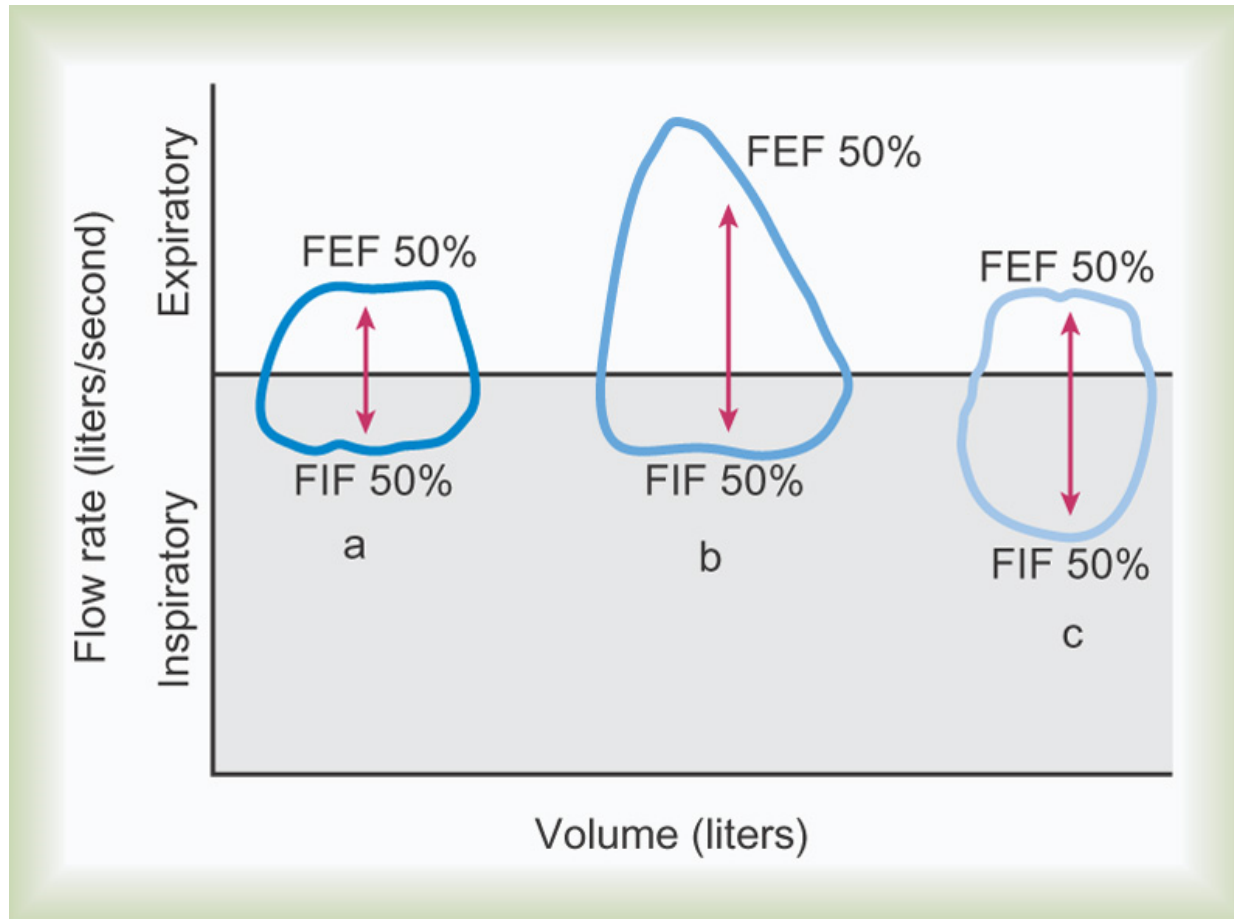
**Figure 08-07.** Flow volume loop. These flow volume loops are typical patterns seen with **(A)** normal, **(B)** restrictive lung diseases, **(C)** upper airway obstruction, and **(D)** severe chronic obstructive lung disease

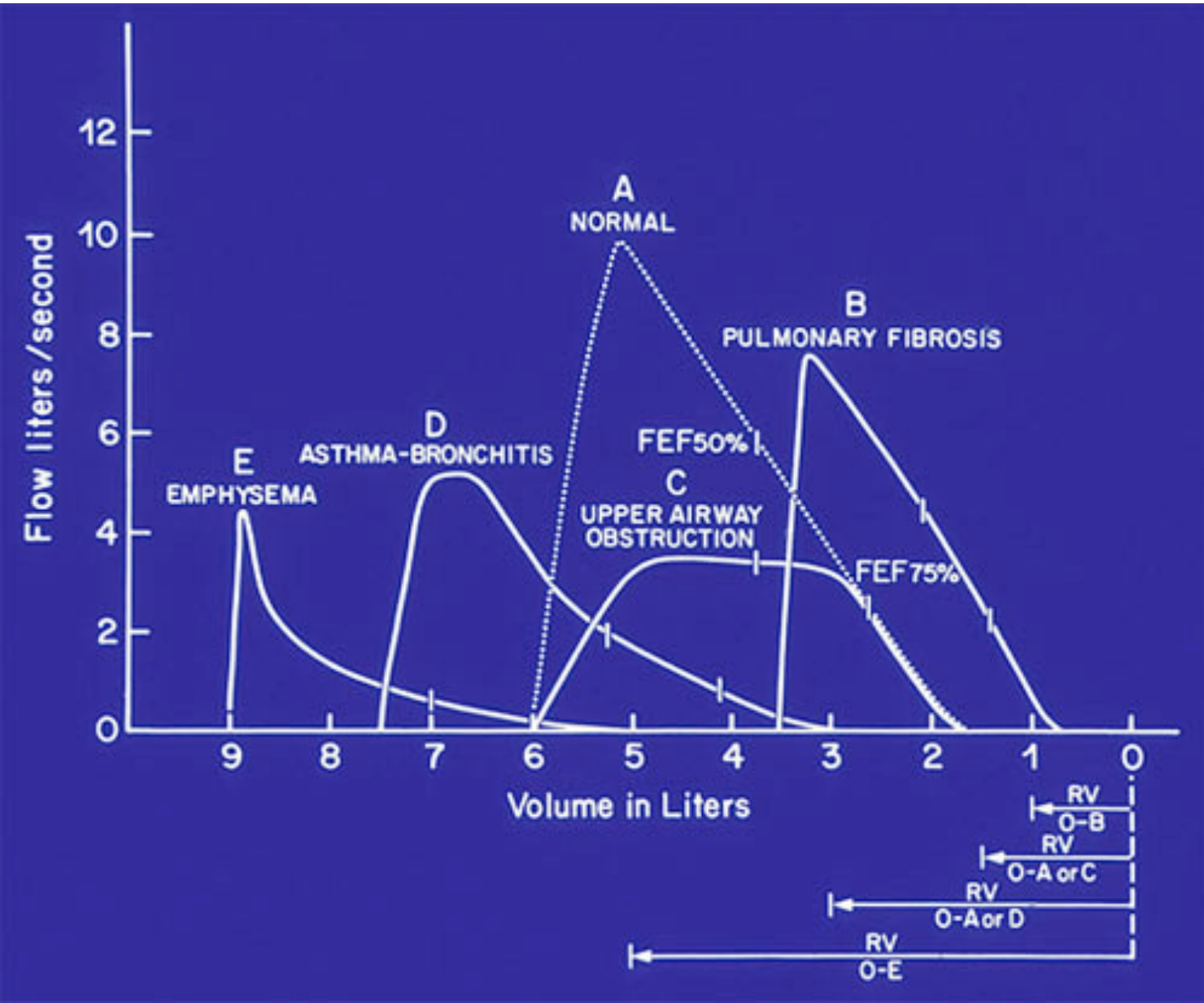




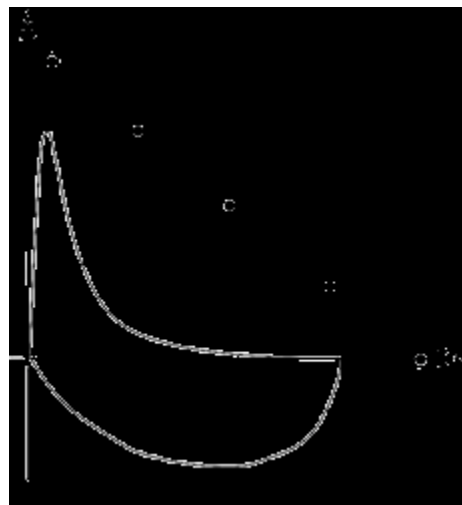
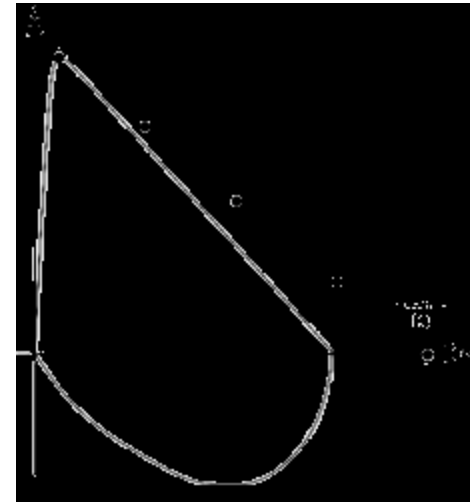
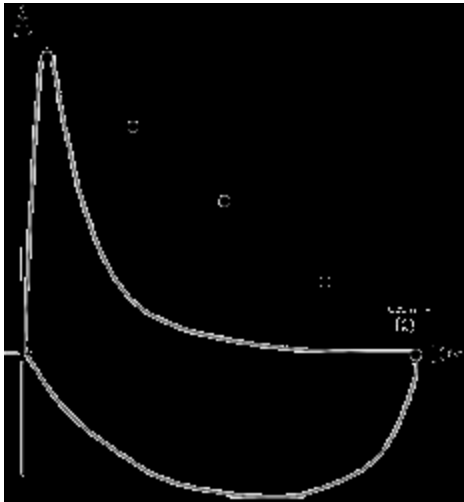


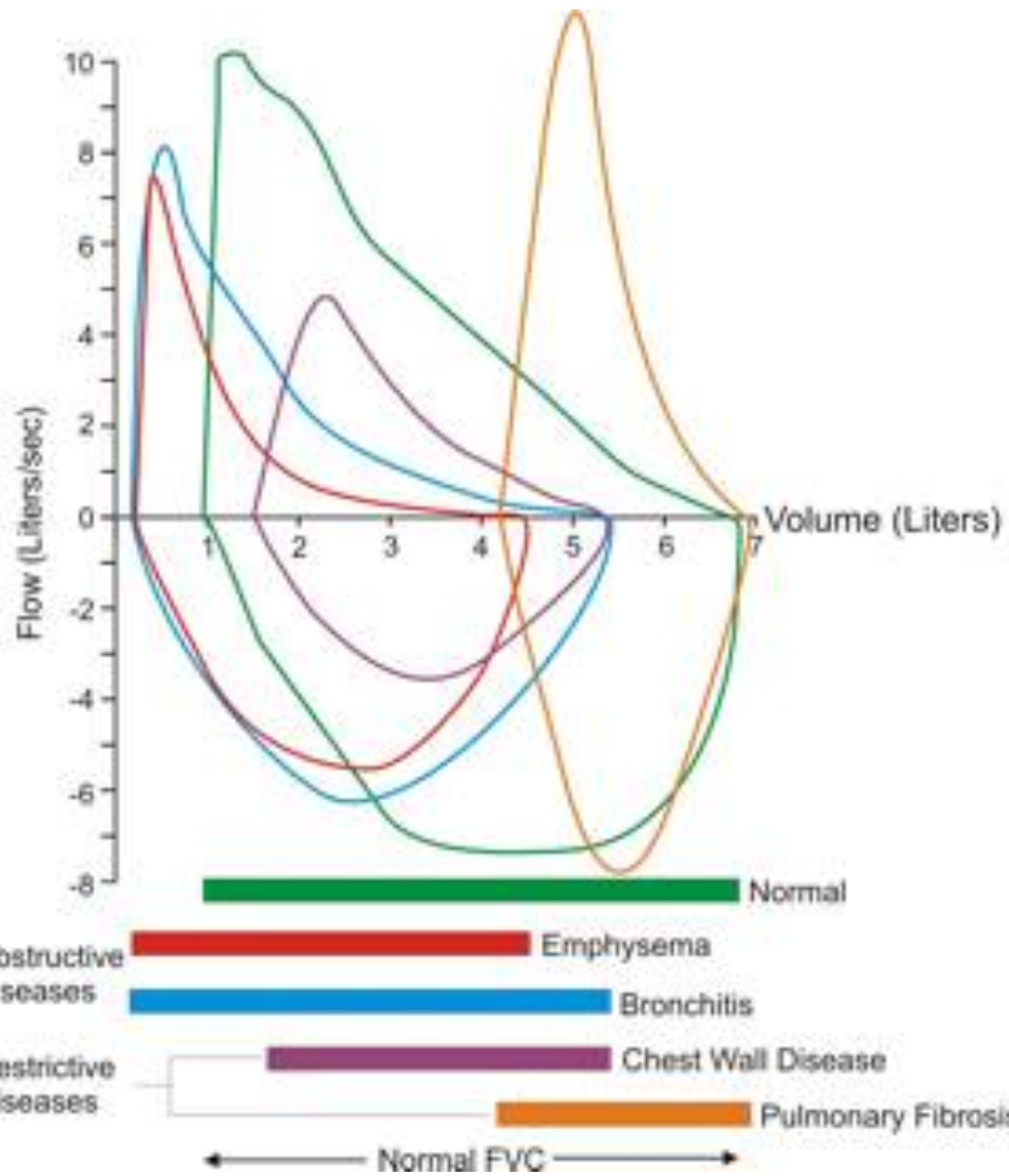
Flow-volume loops of (a) fixed upper airway obstruction, (b) variable extrathoracic upper airway obstruction, and (c) variable intrathoracic upper airway obstruction.





# Identify these loops!





# Bronchodilators

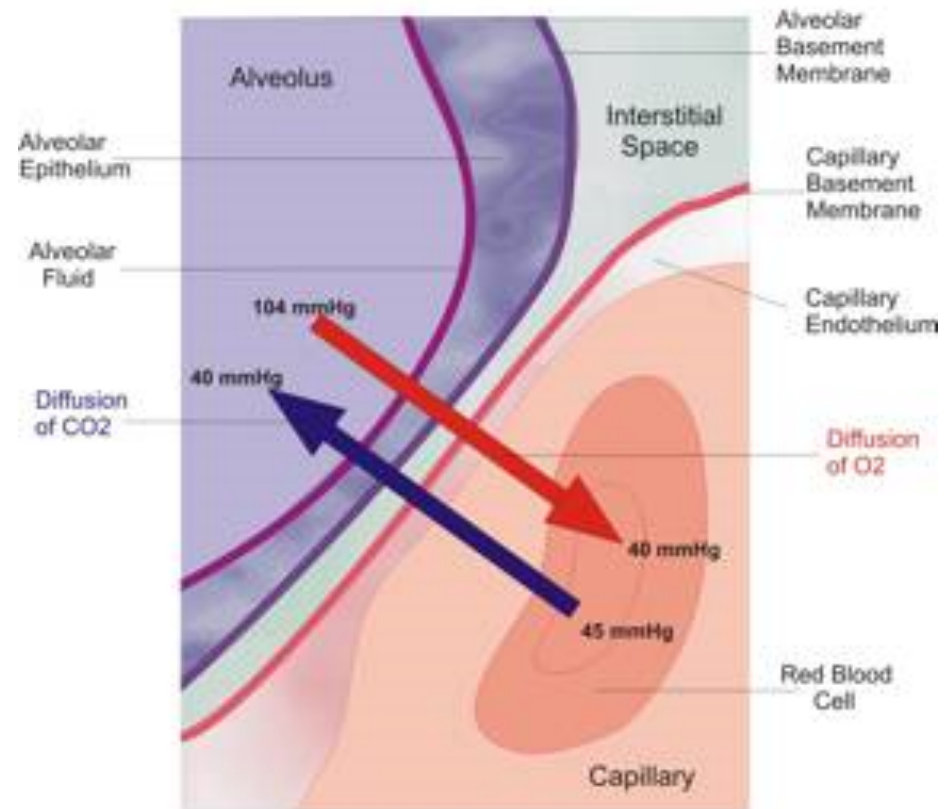


ADAM.

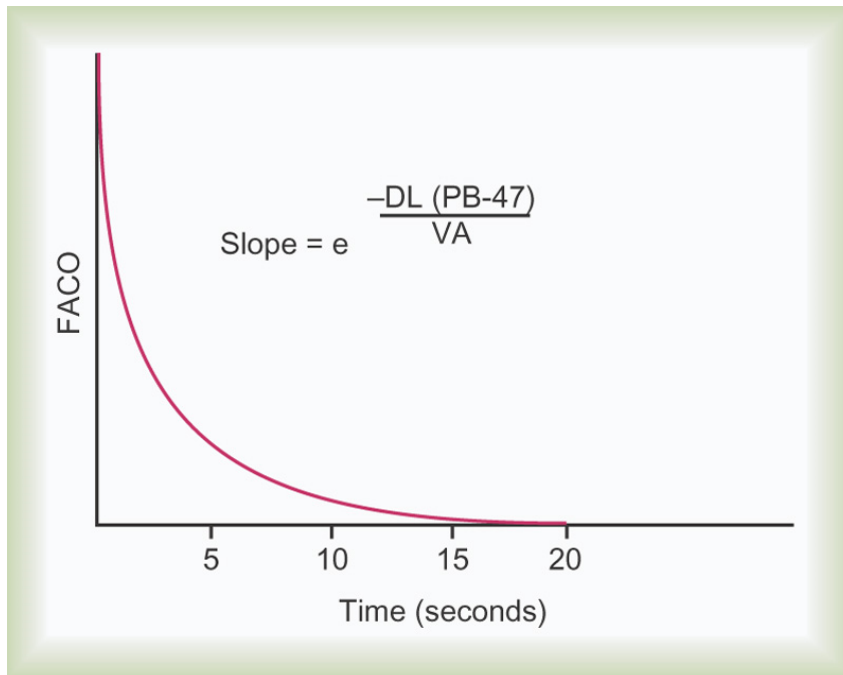
- Test before and after to assess the degree of reversibility of the airway obstruction
- Medication is not standardized
- A positive response is demonstrated by:
  - FVC increase  $>10\%$
  - $FEV_1$  increase of 200ml or 15% over baseline
  - $FEF_{25-75\%}$  20%-30% increase
- Often given a trial even if no response is seen

# Diffusion Capacity ( $D_L$ )

- Represents the gas exchange capabilities of the lungs
- Measures the ability of gas to diffuse across the alveolar-capillary membrane using carbon monoxide:  $D_{LCO}$



# $D_LCO$



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- Diseases that reduce surface area –  $\downarrow D_L$ 
  - emphysema
- Interstitial altering of the membrane integrity –  $\downarrow D_L$ 
  - Pulmonary fibrosis, Asbestosis, Sarcoidosis

# Other Studies

- **Airway Resistance**
  - Quantifying allows understanding of the severity of the disease
  - Measured using plethysomograph
- **Compliance Studies**
  - Identifies the relative stiffness of the lung
  - Esophageal balloon catheter
- **Nitrogen Washout**
  - Determines if there is gross maldistribution of ventilation
- **Closing Volume**
  - Used for diagnosis of small airway obstruction
- **Respiratory Quotient**
  - Determines the amount of carbon dioxide produced and oxygen consumed



# Exercise Testing

- 6 minute walk test
- Anaerobic threshold
- Exercise challenge
- Ventilatory Capacity

# Bronchoprovocation Testing

- Used to diagnose “occult” asthma
- Challenge the patient with an inhaled bronchoconstrictor – Methacholine (also can use cold air or exercise)
- Object is to determine the minimum level that elicits a 20% decrease in FEV<sub>1</sub>
- Requires bronchodilator ready for use as well as resuscitation equipment!

# ATS Guidelines

- **General Considerations for Lung Function Testing**
- **Standardization of Spirometry**
- **Standardization of the Measurements of Lung Volumes**
- **Standardization of the single breath determination of carbon monoxide uptake in the lung**
- **Interpretive Strategies for Lung Function Tests**
- **Cardiopulmonary Exercise Testing**
- **Guidelines for the Six-minute Walk Test**
- **Guidelines for Methacholine and Exercise Challenge Testing**

# ATS (American Thoracic Society) STANDARDS

1. No coughing: especially during first second of FVC
2. Good start of test: <5% of FVC exhaled prior to a max expiratory effort. (<5% extrapolation)
3. No early termination of expiration: exhalation time of six seconds or a plateau of 2 seconds
4. No variable flows: flow rate should be consistent and as fast as possible throughout exhaled VC
5. Good reproducibility or consistency of efforts: 2 best FVC's and 2 best FEV1's should agree within 5% or 100 ml (whichever is greatest)

# Evaluation/Interpretation of PFT's

## INTERPRETATION CRITERIA

<u>TEST</u>	<u>NORMAL</u>	<u>MILD</u>	<u>MODERATE</u>	<u>SEVERE</u>	
FVC	>80%	61-80%	50-60%	<50%	Restriction
FEV1	>80%	61-80%	50-60%	<50%	Obstruction
PEFR	>80%	61-80%	50-60%	<50%	
FEF25-75	>80%	61-80%	50-60%	<50%	Small Airway Disease
FEV1/FVC	70-75%	60-69%	50-59%	<50%	Obstruction

## POSITIVE RESPONSE TO BRONCHODILATOR

1. FVC: increase greater than 10%
2. FEV1: increase of 200cc or 15% over baseline
3. FEF25-75: 20% increase
4. 2 out of 3 should improve to indicate a positive response

# Evaluation of Results

## Evaluation of the Vital Capacity

- can be reduced in obstructive and restrictive disease
- if VC is reduced, evaluate the TLC
  - if the TLC is increased = obstruction
  - if the TLC is decreased = restriction
- if VC is normal, evaluate the TLC
  - if the FVC is greater than 90% of the SVC = normal
  - if the FVC is less than 90% of the SVC = obstruction

## • Evaluation of the FEV1/FVC

- if the FEV1/FVC is normal then the lungs are normal or restrictive
- if the FEV1/FVC is reduced = obstruction

# Evaluation of Results

- Evaluation of FEF 25-75%
  - if normal then normal lungs or possible restriction
  - if reduced = peripheral obstruction
- Evaluation of the Total Lung Capacity: % pred.
  - increased  
=hyperinflation present  
evaluate the FEV1  
Normal = normal lungs  
Decreased = obstruction
  - Decreased  
evaluate the FEV1  
Normal = restrictive  
Decreased = obstructive and restrictive

# Evaluation of Results

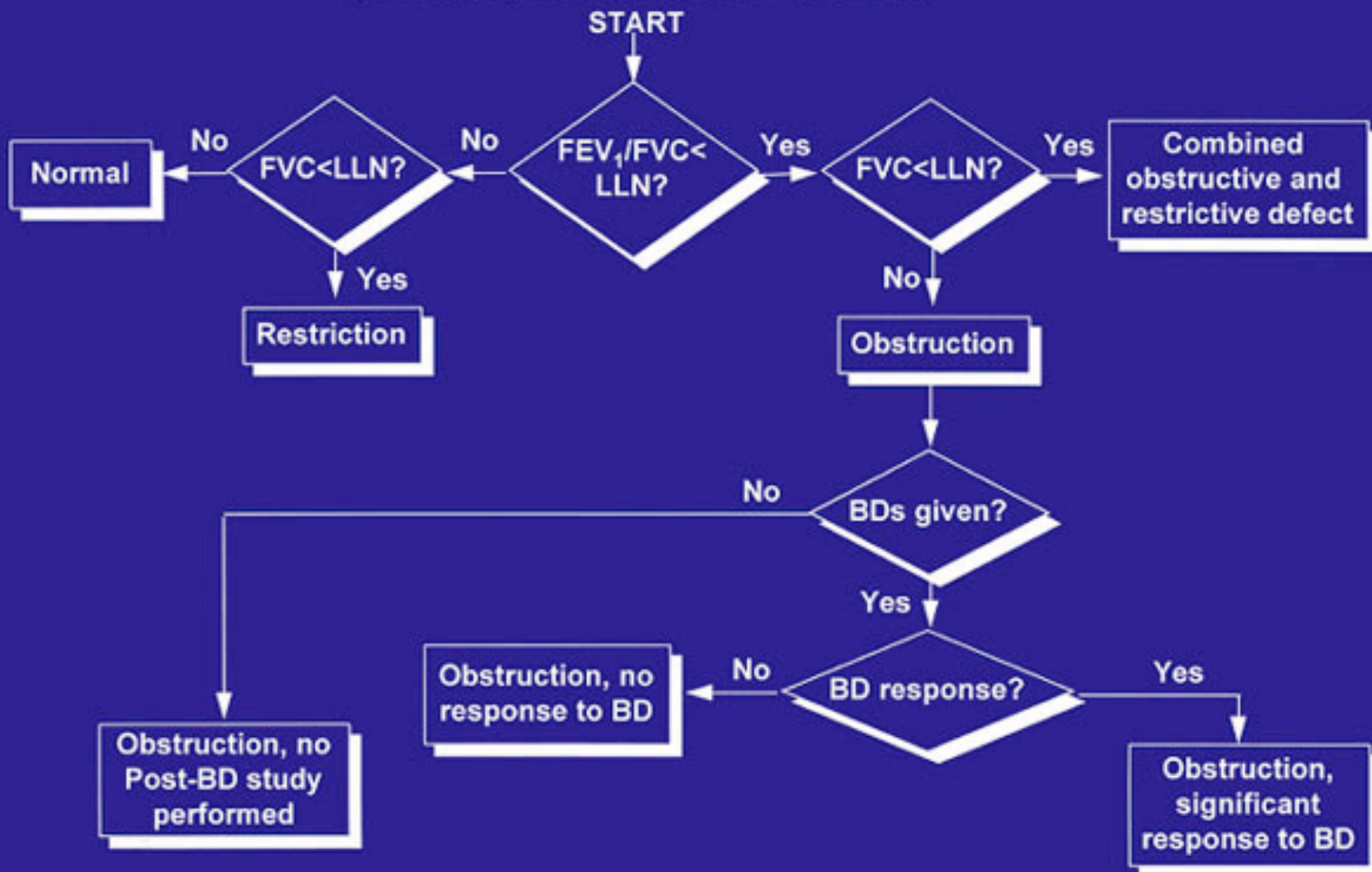
- To differentiate between obstructive and restrictive diseases utilize the DLCO as well

Typical Results of Disease on Ventilatory Function		
	Obstruction	Restriction
FVC	↔ ↓	↓ ↓
FEV <sub>1</sub>	↓ ↓	↔ ↓
FEF <sub>25-75</sub>	↓ ↓	↔ ↓
MVV	↓ ↓	↔ ↓

↔ Normal    ↓ Reduced    ↑ Increased



## Spirometry Interpretation Overview



# Summary

## RESTRICTIVE PATTERN

1. Defined on the basis of a reduction in both the vital capacity and total lung capacity.
2. Residual volume and other volumes and capacities may be variably reduced.
3. Flow rates are normal unless restrictive process is severe.
4. FEV1 is reduced, but the FEV1/FVC will be normal.

## OBSTRUCTIVE PATTERN

1. Defined on the basis of a reduction in one or more pulmonary flow tests.
2. Vital capacity tends to decrease and the residual volume tends to rise with increasing severity of the disease process causing the obstructive pattern.

# Critical Thinking

Both obstructive and restrictive diseases may exhibit decreased FVC and FEV1. How can the two kinds of patterns be differentiated?

FVC and FEV1 are reduced in both obstructive and restrictive disorders for different reasons. With restrictive disease, lung expansion is reduced and all lung volumes are smaller than normal. With obstructive disease there is airway obstruction which slows expiratory flow. FEV1 is reduced because of the increased airway resistance, which decreases expiratory flow rates. FVC is reduced because airway obstruction in the bronchioles causes air trapping in the lungs.

To differentiate between obstructive and restrictive patterns, compare the FEV1 with the FVC using the FEV1/FVC ratio. Those with airway obstructions will exhale less than 70% of their FVC in the 1st second. Those with restrictive disease and/or healthy lungs will be able to exhale more than 70% of their FVC in one second.

# Critical Thinking

A patient has spirometry and lung volumes typical of the obstructive pattern. The FEV<sub>1</sub>, FEV<sub>1</sub>/FVC and FEF's are significantly reduced and the FRC and TLC are increased. Two common obstructive diseases are chronic bronchitis and pulmonary emphysema. How can pulmonary function data differentiate between these two diseases?

THE DLCO! Chronic bronchitis involves mostly airways and is characterized by chronic inflammation of the mucosa, excessive mucus, and bronchospasm; all of which narrow the airways. Pulmonary emphysema primarily involves alveolar structures and is characterized by destruction of alveolar architecture, elastic fibers, and the alveolar capillary membrane. Emphysema decreases gas exchange surface area. Chronic bronchitis does not involve alveoli and therefore does not change surface area for gas exchange. A decreased diffusion capacity is associated with emphysema

# Critical Thinking

In the advanced stages of pulmonary emphysema, the FRC and the RV are increased; in addition the VC is often decreased. Why do these changes occur?

Emphysema is characterized by a destruction of elastic tissue in the lung, which causes a lower lung recoil force. When lung recoil forces decrease, as in emphysema, chest wall expansion forces predominate, the chest wall expands outward pulling the lung with it. A new equilibrium occurs at increased lung volume so the FRC is increased. The RV is increased in emphysema because the VC is decreased because of small airway obstruction. When a person with emphysema tries to exhale completely, his or her bronchioles collapse, trapping air in the lungs. Increased FRC = hyperinflation; Increased RV = air trapping