# PULMONARY FUNCTION TESTS

(Maher K. Tabba MD, MS)

Pulmonary Function Tests:

- ❑ Spirometry
- ❑ Lung Volumes
- ❑ Diffusion Capacity
- ❑ Maximal Voluntary Ventilation (MVV)
- ❑ Maximal Inspiratory Pressure (Pi max)
- ❑ Maximal Expiratory Pressure (Pe max)
- ❑ Arterial Blood Gas (ABG)
- ❑ Walking Oxymetry
- ❑ Bronchochallenge Tests

INDICATIONS:

- ❑ Pulmonary Evaluation:
  - ▪ Presence of impairment
  - ▪ Type of Pulmonary dysfunction
  - ▪ Quantification of impairment in known disea
  - ▪ Monitor the progression of known disease
  - ▪ Monitor the treatment response of known disease
- ❑ Preoperative Assessment:
  - ▪ Estimate the risk for postoperative complications (operability)
  - ▪ Tolerance for lung resection (resectability)
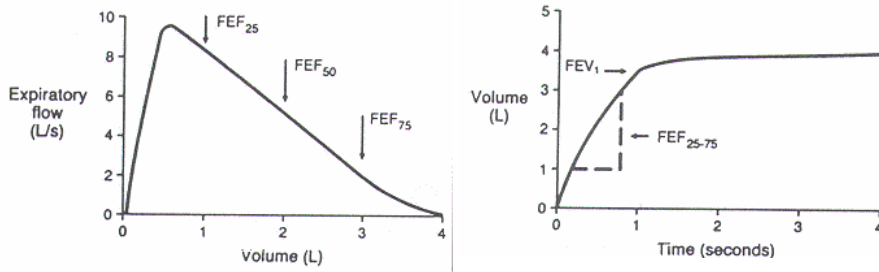- ❑ Disability Evaluation
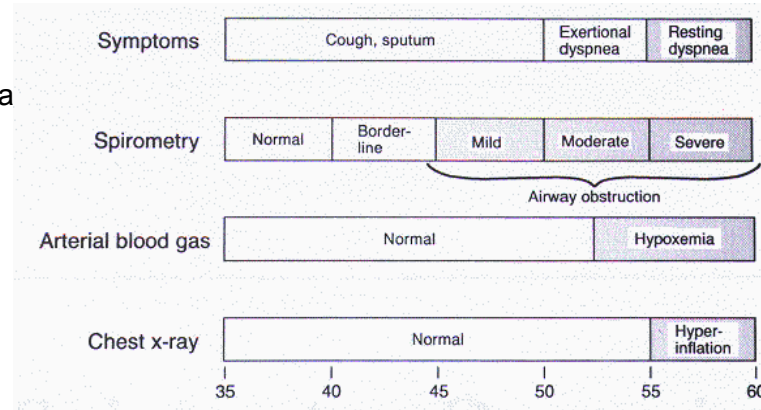
LUNG VOLUMES & CAPACITIES:

- ❑ **Tidal Volume (VT):** The volume of air entering the nose or mouth per breath (500 ml).

- ❑ **Residual Volume (RV):** The volume of air left in the lungs after a maximal forced expiration (1.5L).

- ❑ **Expiratory Reserve Volume (ERV):** The volume of air that is expelled from the lung during a maximal forced expiration that starts at the end of normal tidal expiration (1.5L).

- ❑ **Inspiratory Reserve Volume (IRV):** The volume of air that is inhaled into the lung during a maximal forced inspiration starting at the end of a normal tidal inspiration (2.5L).

- ❑ **Functional Residual Capacity (FRC):** the volume of air remaining in the lungs at the end of a normal tidal expiration (3 L).

- ❑ **Inspiratory Capacity (IC):** The volume of air that is inhaled into the lung during a maximal forced inspiration effort that begins at the end of a normal tidal expiration (VT+IRV=3L).

- ❑ **Vital Capacity (VC):** The volume of air that is expelled from the lung during a maximal forced expiration effort starting after a maximal forced inspiration (4.5L).

- ❑ **Total Lung Capacity (TLC):** The volume of air that is inhaled into the lung after a maximal inspiration effort (5-6 L).
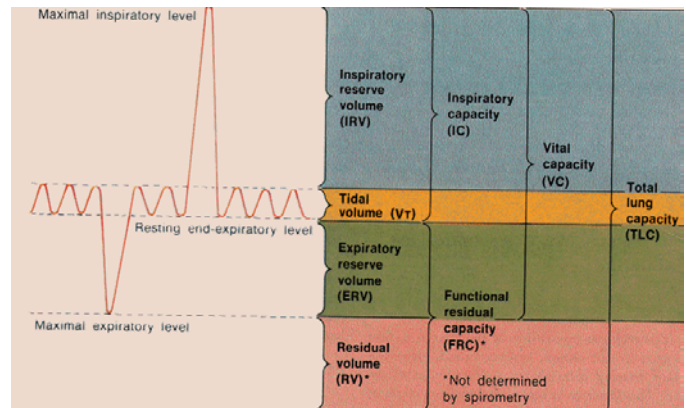
Spirometry:

Measures the lung volume change during forced breathing maneuvers:
- ❑ Forced vital capacity (FVC)
- ❑ Forced expiratory volume in the first second (FEV-1)

Forced Expiratory Vital Capacity Maneuver

Patient inspires maximally to total lung capacity, then exhales into spirometer as forcefully, as rapidly, and as completely as possible

Spirometry	Obstruction	Restriction
FEV-1	Decreased (--)	Decreased (-)
FVC	Decreased (-)	Decreased (-)
FEV-1/FVC	Decreased (definition)	Normal & Increased
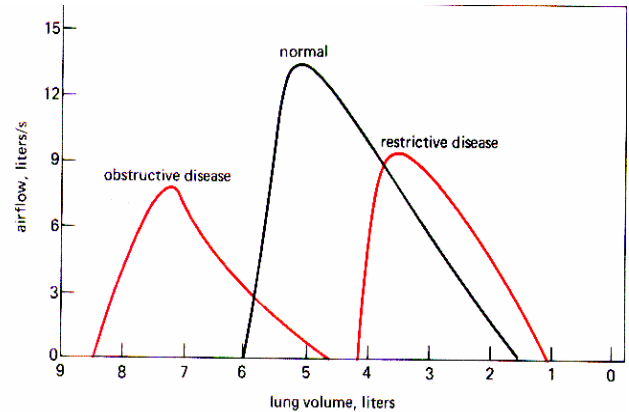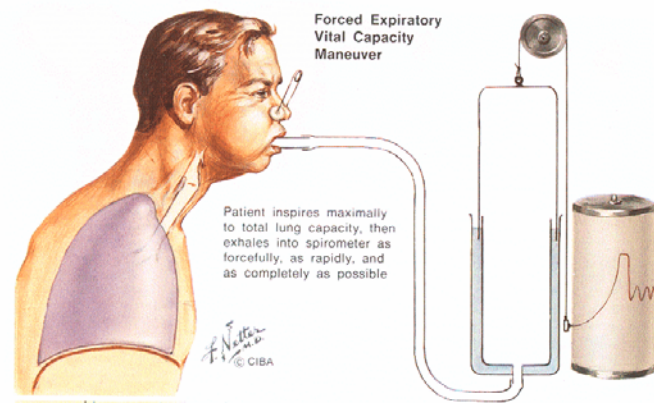
COPD STAGING

Stage I	Stage II	Stage III
Mild	Moderate	Severe
(FEV$_1$ ≥50%)	(FEV$_1$ 49%-35%)	(FEV$_1$ <35%)

American Thoracic Society Guideline

Stage 0	Stage I	Stage IIA	Stage IIB	Stage III
At Risk	Mild	Moderate	Moderate	Severe
(FEV$_1$ Normal)	(FEV$_1$ ≥80%)	(FEV$_1$ 79%-50%)	(FEV$_1$ 49%-30%)	(FEV$_1$ <30%)

Global Initiative for Chronic Obstructed Lung Disease (GOLD) Guideline

❖ **Obstructive Lung Diseases:**
- ❑ Emphysema & Chronic Bronchitis
- ❑ Cystic Fibrosis
- ❑ Asthma
- ❑ Bronchiectasis
- ❑ Some Interstitial Lung Disease: (combined)

❖ **Restrictive Lung Diseases:**

Lung	Pleural cavity	Chest wall	Muscle
Resection (lobectomy, pneumonectomy)	Effusion	Scleroderma	Neuromuscular disease
Atelectasis	Enlarged heart	Ascites	Old polio
Stiff lung – eg, fibrosis	Tumor	Pregnancy	Paralyzed diaphragm
CHF – engorged vessels, edema		Obesity	
Thickened pleura		Kyphoscoliosis	
Tumor		Splinting due to pain	
Airway obstruction – asthma, chronic bronchitis			
Emphysema			

Pre and Post Bronchodilator Spirometry:
- ❑ Goal: to evaluate the reversibility of the airway obstruction.
- ❑ Technique : repeat the spirometry after the treatment with bronchodilator.
- ❑ Criteria: required two criteria at the same time:
  200 ml and 12% (both) change in either FEV-1 or FVC
- ❑ Patient with Reversible Airway Obstruction responds to treatment with:
  - **_Bronchodilator (short & long acting)_**
  - **_Steroid inhaler_**

Spirometry:
- ❑ Detects the obstructive lesions in the major airways.
- ❑ Characterizes the lesion:
  - **_A-Location_** of the lesion:
    - *Intrathoracic*
    - *Extrathoracic*

  - **_B-Behavior_** of the lesion during rapid inspiration and expiration:
    - *Fixed*
    - *Variable*
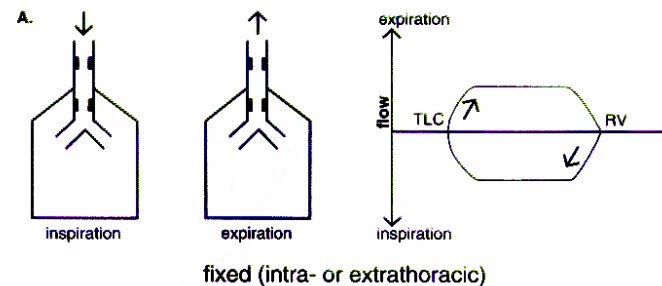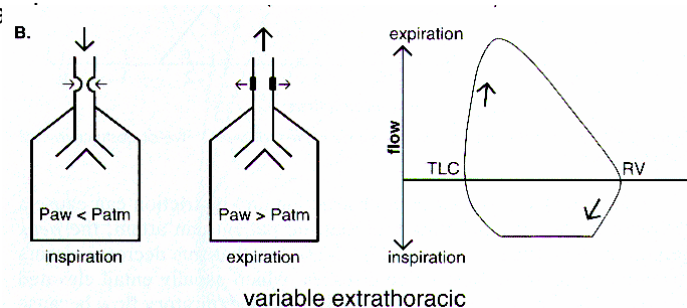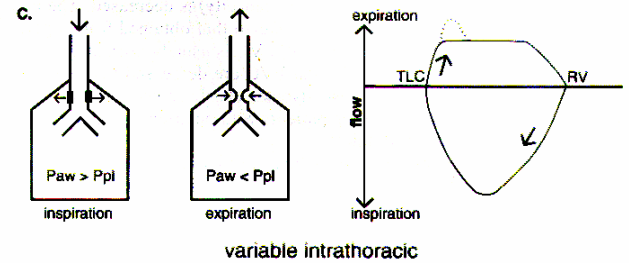
- ❖ **Variable Intrathoracic Lesion:**
  Examples: Tracheomalacia & Intratracheal tumor.
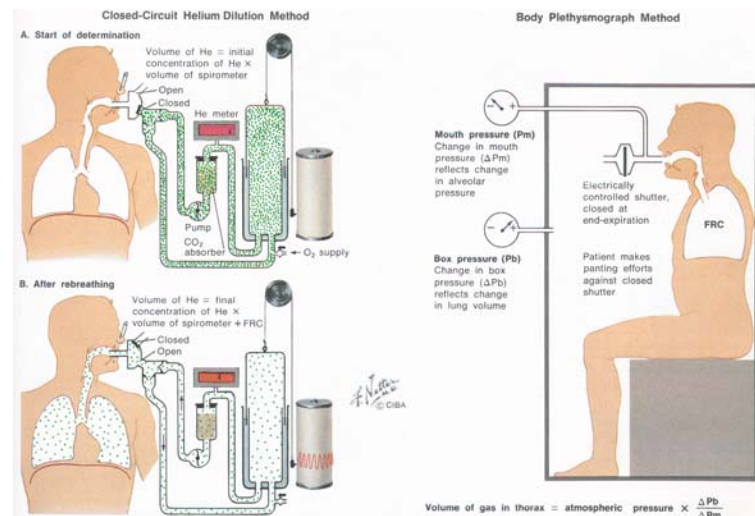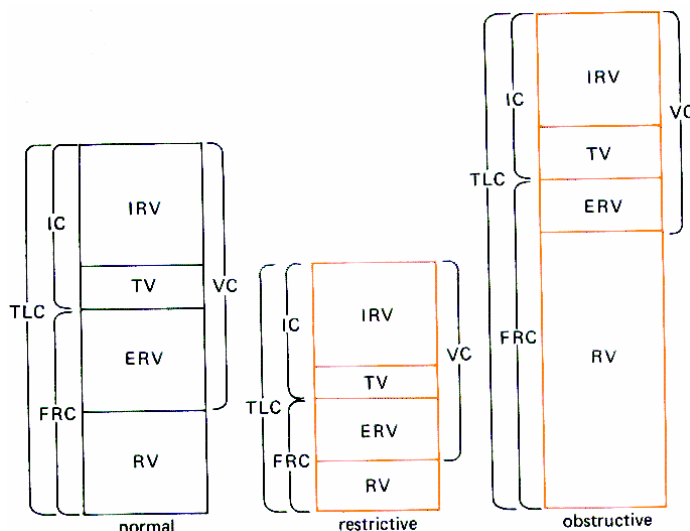
- ❖ **Variable Extrathoracic Lesion:**
  Examples: Vocal cord paralysis, Goiter, and Tumor

- ❖ **Intra or Extrathoracic Fixed Lesion:**
  Examples: Tracheal stenosis & surgical stricture, and compressing mass.

C.
Paw > Ppl Paw < Ppl
inspiration expiration
variable intrathoracic

B.
Paw < Patm Paw > Patm
inspiration expiration
variable extrathoracic

A.
inspiration expiration
fixed (intra- or extrathoracic)

Lung Volumes:

normal   restrictive   obstructive

Closed-Circuit Helium Dilution Method

A. Start of determination

Volume of He = initial concentration of He × volume of spirometer

B. After rebreathing

Volume of He = final concentration of He × volume of spirometer + FRC

Body Plethysmograph Method

Mouth pressure (Pm) Change in mouth pressure (ΔPm) reflects change in alveolar pressure

Box pressure (Pb) Change in box pressure (ΔPb) reflects change in lung volume

Patient makes panting efforts against closed shutter

Electrically controlled shutter, closed at end-expiration

Volume of gas in thorax = atmospheric pressure × $\frac{\Delta Pb}{\Delta Pm}$

Diffusion Capacity:

Estimates the transfer of oxygen in the alveolar air to the red blood cell.
Factors that influence the diffusion:

1) Area of the alveolar-capillary membrane (A)
2) Thickness of the membrane (T)
3) Driving pressure
4) Hemoglobin

A-Decreased:
1) Decrease the *area* of the diffusion:
Lung/lobar resection, bronchial obstruction, and IPF.

2) Increase the *thickness* of the alveolar-capillary membrane:
IPF, CHF, pulmonary vascular diseases

3) Decrease the *driving pressure*: smoking, CO exposure

4) *Hemoglobin*: Anemia, Hemoglobinopathy.

B- Increased:
- Pulmonary hemorrhage
- Polycythemia
- Early CHF
- Asthma
- Exercise
- Obesity
- Left to right shunt
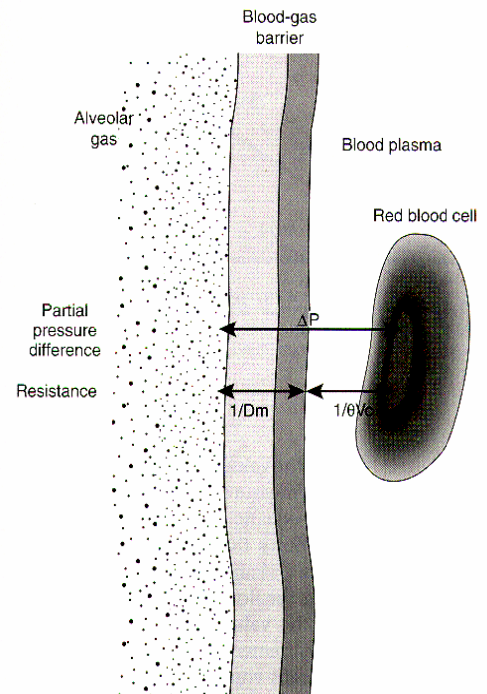
Technique:

- He or CH4 to measure the alveolar volume (VA)
- CO to measure the diffusion capacity (DLCO)
- DLCO
- DLCO corrected to Hgb *(DLCO corr Hgb)*
- DLCO corrected to CO
- Alveolar Volume
- DLCO adjusted to the alveolar volume *(DLCO/VA)*

DLCO adjusted to Hgb	↓	↓
Alveolar Volume (VA)	↓	N
DLCO/VA	N	↓
Example	(Restriction)	(V/Q mismatch)

Walking Oxymetry:

Goal: detects the hidden diffusion defect.
Technique: check O2 saturation at rest, 4 mins and 6 mins walk.
- ❏ Walking Oxygen Desaturation:
  1. Diffusion defect.
  2. V/Q mismatch
  3. Shunt
- ❏ Criteria for Oxygen Supplementation (Home Oxygen):
  1. PO2 <55 or Oxygen Saturation <88%
  2. PO2 <59 with:Pulmonary Hypertension or Polycythemia

Maximal Voluntary Ventilation (MVV):

Measures the ventilatory reserve
The subject breaths as hard and fast as possible for 10-15 sec, and then adjust it to 1 min.
MVV = FEV-1 times 35-40
Decreases:
- •Poor effort
- •Neuromuscular diseases
- •Obstructive & restrictive lung diseases
- •Heart diseases
- •Obesity

Maximal Inspiratory Pressure (Pi max) & Maximal Expiratory Pressure (Pe max):

Goal: To measure the strength of the respiratory muscles.
Technique: the amount of pressure the subject can generate in:
Deep inspiration (inspiratory muscles): (Pimax)
Deep expiration (expiratory muscles): Pemax
Normal value: Pimax (-60) & Pemax (+120) cm H2O
Indications:
- ❏ Neuromuscular diseases
- ❏ Unexplained decrease in VC & MVV

Weaning (Pimax > -30)

Arterial Blood Gas:
- ❏ Oxygenation (PO2 and FiO2) & Ventilation (PCO2 and PH)
- ❏ Acid – Base balance (PCO2, HCO2, and PH)

Bronchochallenge Tests:

Goal: evaluate the airway hyperresponsivness (asthma).
Technique: Methacholine, Histamine, Cold, Exercise…etc.
Criteria: 20% decrease in baseline FEV-1

Types of PFT:

- **Evaluate Lung Mechanics:**
    - Volume
    - Flow
    - Resistance
    - Compliance
    - Airway Hyperractivity
- **Evaluate Respiratory Muscles:**
    - Maximal Voluntary Ventilation (MVV)
    - Maximal Inspiratory Pressure (Pi max)
    - Maximal Expiratory Pressure (Pe max)
    - Seating & Supine Spirometry
- **Evaluate Gas Exchange:**
    - PO_2 & alveolar-arterial oxygen pressure difference
    - Physiologic dead space ventilation
    - Diffusion capacity

Interpreting PFT:

General Approach to Interpretation:
- A. Is the test interpretable? "*garbage in, garbage out*".
- B. Are the results normal?
- C. What are the pattern and severity of abnormality?
- D. What does this mean for this patient?

General Information:
- Age & Sex
- Weight
- Diagnosis
- The patient's effort during the test
- Does the study meet the ATS criteria (Acceptability & Reproducibility)

Pulmonary Functions:
- Spirometry:
    - FEV-1/FVC ratio
    - FEV-1 & FVC
    - Flow-Volume loop
    - MVV & Pimax or Pemax

- Lung volumes: (TLC, RV, RV/TLC ratio)
- Diffusion Capacity: (DLCO corr Hgb, DLCO/VA).
- Arterial Blood Gas
- Comparison with previous study

Abnormal Pulmonary Function Patterns:

1. Obstructive
2. Restrictive
3. Neuromuscular weakness
4. Pulmonary Vascular
5. Poor Effort