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 disease
  - 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)

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Obstruction</th>
<th>Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV-1</td>
<td>Decreased (--)</td>
<td>Decreased (-)</td>
</tr>
<tr>
<td>FVC</td>
<td>Decreased (-)</td>
<td>Decreased (-)</td>
</tr>
<tr>
<td>FEV-1/FVC</td>
<td>Decreased (definition)</td>
<td>Normal &amp; Increased</td>
</tr>
</tbody>
</table>

**COPD STAGING**

*American Thoracic Society Guideline*

<table>
<thead>
<tr>
<th>Stage I</th>
<th>Stage II</th>
<th>Stage III</th>
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<tbody>
<tr>
<td>Mild (FEV₁ ≥ 50%)</td>
<td>Moderate (FEV₁ 49%–75%)</td>
<td>Severe (FEV₁ &lt; 35%)</td>
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</tbody>
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*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:**

- Resection (lobectomy, pneumonectomy)
- Effusion
- Scleroderma
- Neuromuscular disease
- Thromboembolic disease
- Enlarged heart
- Atelectasis
- Acute respiratory failure
- Old age
- CHF – engorged vessels, edema
- Paralyzed diaphragm
- Thickened pleura
- Obesity
- Kyphoscoliosis
- Airway obstruction – asthma, chronic bronchitis
- Splinting due to pain

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**Diagram:**
- Forced Expiratory Vital Capacity Maneuver
- Patient inspires maximally to total lung capacity, then expiries into spirometer as forcibly, as rapidly, and as completely as possible

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**Graphs:**
- COPD staging
- Airflow (L/min)
- Lung volume (liters)
- Peak expiratory flow
- Maximal curve
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.

Lung Volumes:
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)*
**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 Hyperreactivity

- **Evaluate Respiratory Muscles:**
  - Maximal Voluntary Ventilation (MVV)
  - Maximal Inspiratory Pressure (Pi max)
  - Maximal Expiratory Pressure (Pe max)
  - Seating & Supine Spirometry

- **Evaluate Gas Exchange:**
  - PO2 & 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