PULMONARY FUNCTION MEASUREMENTS
MODULE D

Objectives
At the completion of this module you will:
- List the four lung volumes including the following information:
  - Description, Patient Instructions (if applicable), and Normal Value.
- List the four lung capacities including the following information:
  - Description, Patient Instructions (if applicable), and Normal Value.
- Identify the major volumes, capacities, and flow variables from a graphic tracing and state when they would be used.

Objectives
At the completion of this module you will:
- Distinguish between effort-dependent and effort independent tests.
- Describe dynamic compression.
- Describe equal pressure point.
- State the significance of lung diffusion testing.
- State the normal Diffusing Capacity of the Lung (DLco)

Readings
- Beachey: Chapter 5
- Egan: Chapter 17
- Very "techie"... Use as support and pay attention to that material I cover in class.

Lung Volumes
- 4 Lung Volumes, 3 of which can be measured with simple spirometry.
  - Tidal Volume (Vt): The volume of air that normally moves into and out of the lungs in one "quiet" breath.
    - Normal: 5-8 ml/kg (70 kg * 7 ml/kg = ~500 ml).
  - Inspiratory Reserve Volume (IRV): The maximum volume of air that can be inhaled after a normal tidal volume.
    - Normal: 3,100 mL
  - Expiratory Reserve Volume (ERV): The volume of air that can be exhaled after a normal tidal volume.
    - Normal: 1,200 mL
  - Residual Volume (RV): The amount of air remaining in the lung after a maximal exhalation.
    - Normal: 1,200 mL
    - Cannot be measured with simple spirometry.

Lung Capacities
- 4 Lung Capacities
  - Vital Capacity (VC): The maximum volume of air that can be exhaled after a maximal inspiration (Vt + IRV + ERV)
    - Normal: 4,800 mL
  - Slow Vital Capacity (SVC): Exhalation is performed slowly.
  - Forced Vital Capacity (FVC): Forced exhalation (see below)
  - Inspiratory Capacity (IC): The volume of air that can be inhaled after a normal expiration (Vt + IRV).
    - Normal: 3,600 mL
  - Functional Residual Capacity (FRC): The volume of air remaining in the lungs after a normal exhalation (ERV + RV)
    - Normal: 2,400 mL
  - Total Lung Capacity (TLC): The maximum amount of air that the lungs can accommodate (IC + FRC)
    - Normal: 6,000 mL
  - Residual Volume/Total Lung Capacity Ratio: The percentage of the TLC occupied by the RV (RV/TLC x 100%)
    - Normal: 20%
Directions for Lung Volume/Capacity Measurements

- **Tidal Volume** (Vt): Breathe normally in and out.
- **Inspiratory Reserve Volume** (IRV): Inhale as much as you can from a normal inhalation.
- **Expiratory Reserve Volume** (ERV): Exhale as much as you can from a normal exhalation.
- **Residual Volume** (RV): This volume cannot be measured directly with simple spirometry.
- **Slow Vital Capacity** (SVC): Take a deep breath in, as deep as you can, and then blow it out slowly until you can’t blow out any more.

- **Forced Vital Capacity** (FVC): Take a deep breath in, as deep as you can, and then blow it as hard and fast as you can until you can’t blow out any more.
- **Inspiratory Capacity** (IC): Inhale as much as you can from a normal exhalation.
- **Functional Residual Capacity** (FRC): This volume cannot be measured directly with simple spirometry.
- **Total Lung Capacity** (TLC): This volume cannot be measured directly with simple spirometry.

Indirect Measurements of RV

- The residual volume (and the capacities which have it as a part – FRC & TLC) must be measured indirectly by one of three methods:
  - Helium Dilution – **Closed Circuit Method**
  - Nitrogen Washout – **Open Circuit Method**
  - Body Plethysmography
Lung Disease Classification

- Lung diseases are typically classified as being either obstructive or restrictive.

Restrictive
- Pneumonia
- ARDS

Obstructive
- Cystic Fibrosis
- Bronchieactasis
- Asthma
- Bronchitis (Chronic)
- Emphysema

Obstructive Lung Disease

- Obstructive lung diseases have difficulty in getting the air out.
- They are characterized by a reduction in flow.
- They are also associated with an increase in trapped gas at the end of a normal breath (Increased RV, FRC, TLC & RV/TLC)

Restrictive Lung Disease

- Restrictive lung diseases have difficulty in getting the air in.
- All lung volumes are reduced.
- They have normal flow measurements.

PFT – Part II

Pulmonary Mechanics

Objectives

At the completion of this module you will:
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- Describe dynamic compression.
- Describe equal pressure point.
- State the significance of lung diffusion testing.
- State the normal Diffusing Capacity of the Lung (DLCO)
Pulmonary Mechanics

- Forced Vital Capacity (FVC)
- Forced Expiratory Volume Timed (FEV1)
- Forced Expiratory Volume1 Sec/Forced Vital Capacity Ratio (FEV1/FVC)
- Forced Expiratory Flow 25%-75% (FEF25%-75%)
- Forced Expiratory Flow 200-1200 (FEF200-1200)
- Peak Expiratory Flow Rate (PEFR, PF)
- Maximum Voluntary Ventilation (MVV)
- Flow-Volume Loop

**Forced Vital Capacity**

- Maximum volume of gas that can be exhaled as forcefully and rapidly as possible after a maximal inspiration.
- Most commonly performed test.
- Usually equal to the SVC.
- Decreased with obstructive lung disease

| FEV1/FVC | 6-2.5=3.5 L |

**Forced Expiratory Volume Timed**

- The maximum amount of gas that can be exhaled within a specific time period.
- A VOLUME.
- Expressed at different time increments: 0.5, 1, 2, and 3 seconds.
- Decreased with obstructive lung disease.
- Your LUNG NUMBER!

**Forced Expiratory Volume/Forced Vital Capacity Ratio**

- The ratio of volume of gas exhaled in a specific time to the total amount exhaled.
- The FEV1% is the most common one used.
- 83% of the FVC is usually forcefully exhaled in one second.
- A value below 70% is indicative of disease.
- In an obstructed disease BOTH the FVC and FEV1% is reduced.
- In a restricted disease ONLY the FVC is reduced. The FEV1% is normal (or even increased).

**Forced Expiratory Flow 25%-75%**

- The FEF25%-75% is the average flow rate that occurs during the middle 50 percent of an FVC measurement.
- Normally 4.5 L/sec for men, 3.5 L/sec for women.
- Decreased with age and obstructive lung disease.
- Reflects defects with medium to small airways.
**Forced Expiratory Flow 25%-75%**
- Steps to compute:
  - Determine FVC in L.
  - Multiply by 0.25 (25%).
  - Plot that volume on the curve.
  - Multiply the FVC by 0.75 (75%).
  - Plot that volume on the curve.
  - Draw a line connecting the two points and extending in both directions.
  - Find a point where the line crosses two “time” marks.
  - Determine the volume change between these two marks.
  - Express as L/sec.

**Forced Expiratory Flow 200-1200**
- The FEF200-1200 is the average flow rate that occurs between 200 and 1,200 mL of the FVC.
- First 200 mL is ignored because of inertia and the response time of the equipment.
- Good index of larger airways.
- 8 L/sec in men; 5.5 L/sec in women.
- Decreased with age and obstructive lung diseases.
- Similar process of plotting the line.

**Peak Expiratory Flow Rate**
- The maximum flow rate that can be achieved during an FVC maneuver.
- Most common bedside measurement for evaluating acute lung disease (asthma).
- Very effort dependent.
- 10 L/sec for men; 7.5 L/sec for women.
- Reduced with age and obstructive diseases.
- Determined by drawing a line that represents the sharpest tangent to the curve.

**FVC, FEV1.0, and FEF25%-75%**
- Note the size of the FVCs.
- Note the slope of the FEF25%-75% curves.
- Compare Obstructive & Restrictive to Normal.
Maximum Voluntary Ventilation

- The largest volume of gas that can be breathed voluntarily in and out of the lungs in one minute.
- The test actually only lasts 12 to 15 seconds and the value is extrapolated out to one minute.
- 170 L/min in men; 110 L/min in women.
- Decreased with age and obstructive disease.

Flow-Volume Loop

- Graphic representation of the expiratory FVC maneuver followed by a inspiratory FVC.
- Expiratory curve is on top, inspiratory curve is on the bottom.
- Obstructive patterns have a “scooped” out expiratory curve.

Pre- and Post-Bronchodilator

- Repeat pulmonary function measurements after administering a bronchodilator to see if any obstructive component is reversible.
- Reversibility is defined as a 12% or greater improvement in FEV₁ and at least a 200 mL increase in FEV₁.
- % Improvement = (Post FEV₁ - Pre FEV₁) / Pre FEV₁ x 100%

Dynamic Compression of the Bronchial Airways

- The smaller airways do not have cartilaginous support.
- During a forced exhalation, intrapleural pressure will equal the pressure inside the airway.
- The point where the pressures are equal is called the equal pressure point.
- Intrapleural pressures downstream (toward the mouth) from the equal pressure point is in excessive of the pressure within the airway, and the airway collapses.
- This is why SVC > FVC in patients with obstructive airways.
Equipment

- Respirometer
  - Used in prior lab.
  - Measure $V_e$, f, and SLOW Vital Capacity (SVC).
- Bedside Spirometer
  - Measures FVC, FEV1, FEV1%, FEF25%-75%, PEFR.
  - Expiratory maneuver or both Inspiratory & Expiratory.
- Peak Flow

PEAK FLOW:
Predicted: ______________

Attempt:
#1 ______________
#2 ______________
#3 ______________
Average: ______________

MINUTE VENTILATION
Minute Volume: ______________
Respiratory Rate: ______
Average Tidal Volume: ______________
Slow Vital Capacity: ______________

Bedside Screen
FVC: ______________ % Predicted: ____________
FEV1: ______________ % Predicted: ____________
FEV1%: ______________
FEF25-75%: ______________
Interpretation: __________________________
Predicted Values
- Based upon linear regression equations from “normal” subjects.
- Based upon
  - Height
  - Age
  - Gender
  - Race?
  - NOT WEIGHT!
- 80 to 120% of predicted considered “normal”.
- EXCEPTION IS FEV1/FVC RATIO – < 70% IS ABNORMAL.

Interpretative Strategy

<table>
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<th>Is the FEV1 less than 70% of predicted?</th>
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<tr>
<td>NO</td>
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<td>NO</td>
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- NO LUNG DISEASE
- OBSTRUCTIVE LUNG DISEASE
- RESTRICTIVE LUNG DISEASE

Peak Flow Predicteds
- Male:
  - $[(0.0002492) \times (Ht)^2] - (0.001301)$

Example Problems
- Module D - Pulmonary Function Measurements.doc