NOTE: A very useful “Study Guide”!

This Pre-lab guide takes you through the important concepts that were discussed in the lab videos. There will be some “conceptual questions” on the lab practical … it will not be all “anatomy”!

Study Guide

Check Your Knowledge, before the Practical:

1. Understand the relationship between volume and pressure. Understand the three respiratory pressures outlined in this lab: atmospheric, intrapulmonary, and pleural. Understand the basics of inhalation and exhalation.

2. Recognize all equipment used.

3. From the spirogram diagram, know the volumes and capacities as listed in this worksheet.

4. From the vitalometer readout, be able to measure “timed vital capacity” ("timed FEV" or FEV₁) and be able to tell if a patient is within the normal range or not. Also, recognize and measure Vital Capacity (FVC on the graph).

5. Define obstructive versus restrictive lung disorders. What is the difference between a “static” and a “dynamic” respiratory test?

6. On Microscopes:
   - ID Normal versus Abnormal.
   - ID person with Emphysema. ID large alveoli.
   - ID person with Lung cancer. ID tumor.
   - ID person with Black Lung. Know you are looking at fibrosis.
I. Respiratory Volumes and Capacities

Inhalation and Exhalation

Ventilation is the act of moving air in and out of the lungs. In class, we saw that during inhalation we increase the volume of the thoracic cavity by contracting and flattening the diaphragm, while exhalation is the reverse:

Recall that forced expiration involves the abdominal muscles compressing the contents of the abdominal cavity, while forced inspiration involves the sternocleidomastoid and other muscles lifting and expanding the ribcage.

Volumes and Capacities

Respiratory (lung) volumes are those volumes of air which are exchanged during pulmonary ventilation, and are important indicators of the functioning of the respiratory system. They can be measured through the use of a spirometer. There are four pulmonary lung volumes that, when added together, equal the maximum volume to which the lungs can be expanded. These are:

1. Tidal Volume (TV) is the volume of air inspired or expired with each normal breath; it amounts to about 500 milliliters in the adult male.

2. Inspiratory Reserve Volume (IRV) is the extra volume of air that can be inspired over and above the normal tidal volume when the person inspires with full force; it is usually equal to about 3100 milliliters.

3. Expiratory Reserve Volume (ERV) is the maximum extra volume of air that can be expired by forceful expiration after the end of a normal tidal expiration; this normally amounts to about 1200 milliliters.

4. Residual Volume (RV) is the volume of air remaining in the lungs after the most forceful expiration; this volume cannot be voluntarily exhaled, so it must be measured by other methods than those available to us; this volume averages about 1200 milliliters.
Pulmonary Capacities are the sum of two or more of the volumes, and are what we look for in pulmonary diseases. Capacities are measured in volume units. There are four:

1. **Inspiratory Capacity (IC)** equals the tidal volume plus the inspiratory reserve volume. This is the amount of air (about 3600 milliliters) a person can breathe in, beginning at the normal expiratory level and distending the lungs to the maximum amount. \( IC = TV + IRC \)

2. **Functional Residual Capacity (FRC)** equals the expiratory reserve volume plus the residual volume. This is the amount of air that remains in the lungs at the end of normal expiration (about 2400 milliliters). \( FRC = ERV + RV \)

3. **Vital Capacity (VC)** equals the inspiratory reserve volume plus the tidal volume plus the expiratory reserve volume. This is the maximum amount of air a person can expel from the lungs after first filling the lungs to their maximum extent and then expiring to the maximum extent (about 4800 milliliters). \( VC = IRV + TV + ERV \)

4. **Total Lung Capacity (TLC)** is the maximum volume to which the lungs can be expanded with the greatest possible effort (about 6000 milliliters); it is equal to the vital capacity plus the residual volume. \( TLC = IRV + TV + ERV + RV \)

We can graph these volumes and capacities (averages are in red):

**FEV₁ - MEASUREMENT OF LUNG FUNCTION: TIMED FORCED EXPIRATORY VOLUME (1 SECOND)**

Pulmonary function tests are often used in diagnosis of respiratory disease. There are 2 categories of tests:

- **Static lung tests**: simple lung volume and capacity measurements using a spirometer,
- **Dynamic testing**: examines the rate or speed of exhalation.

Please take note of these terms, as they may have not been discussed in the videos!
The rate of exhalation is often affected in obstructive lung disease (see below). This test is also known as a "forced vital capacity" or "FVC" because the subject first maximally inhales and then maximally exhales into the spirometer.

Forced Expiratory Volume (timed), or FEV₁ ("in one second") is a rapid but valuable test of lung function. Rate of airflow is volume/time. We express this as a percent, in order to take into account the subject’s body size.

Example in image: if a 200 lb. male has a FEV₁ of 4000 ml, while a 105 lb. male has an FEV₁ of 3500 ml, which may be due to body size! We get rid of that chance by dividing their FEV₁ values by their FVC, which will also be different due to body size. In other words, we report their % of total!!

This is a percent that removes body size from the equation!

FVC, FEV₁, and their relation to Pulmonary Disorders

Chronic pulmonary disorders can be divided into two major classes: obstructive disorders and restrictive disorders. These two classes can be differentiated by the use of the spirometry tests performed in this exercise.

Obstructive disorders: Bronchiolar obstruction can result from inflammation, edema, smooth muscle constriction, and secretions, making it very difficult to pass air through the airways. Diseases like emphysema, bronchitis and asthma are classified as obstructive disorders. These patients usually have a problem with exhaling or gas exchange across the respiratory membrane and their FEV₁/FVC ratio is below 80% (80% is normal).

Restrictive disorders: Lung damage such as alveolar destruction and scarring can result in changes in lung elasticity and thus the total amount of air one can exhale. If a disease is purely restrictive, as in pulmonary fibrosis, the lung loses compliance, becomes difficult to inflate, and the vital capacity decreases. In this disease, the airways may remain unobstructed, resulting in a normal FEV test (rate of airflow), however the vital capacity is reduced. These patients have an increased problem with inhaling sufficient air, therefore their VC will be overall reduced, as will the FEV₁. But, their ratio of FEV₁/FVC will likely remain as 80% (because BOTH numbers are lowered!)

In a disease like emphysema, which becomes both obstructive and restrictive, the FEV test will be abnormal. The obstruction stems from weakened bronchioles and alveoli that have lost much of their elastic fibers. Lack of elastic recoil results in a need for the person to actively exhale, using the muscles of exhalation. The resulting elevated intrathoracic pressure during exhalation actually acts to close off the smaller bronchioles, increasing the resistance of the airways and blocking the very air one was trying so hard to exhale. The outcome is called "air-trapping."
Emphysema, Chronic bronchitis, and COPD:
Chronic obstructive pulmonary disease (COPD) is a chronic inflammatory lung disease that causes obstructed airflow from the lungs. Symptoms include breathing difficulty, cough, mucus production and wheezing. It's caused by long-term exposure to irritating gases or particulate matter, most often from cigarette smoke. People with COPD are at increased risk of developing heart disease, lung cancer and a variety of other conditions.

Lungs can no longer adequately function. Eventually, there is not enough healthy lung tissue to allow you to excrete sufficient CO₂.

Emphysema and chronic bronchitis are the two most common conditions that contribute to COPD.

Chronic bronchitis is inflammation of the lining of the bronchial tubes, which carry air to and from the air sacs (alveoli) of the lungs. It's characterized by daily cough and mucus (sputum) production.

Emphysema is a condition in which the alveoli at the end of the smallest air passages (bronchioles) of the lungs are destroyed as a result of damaging exposure to cigarette smoke and other irritating gases and particulate matter.

Lung cancer
Also known as lung carcinoma, is a malignant lung tumor characterized by uncontrolled cell growth in tissues of the lung. If left untreated, this growth can spread beyond the lung by the process of metastasis into nearby tissue or other parts of the body. Most cancers that start in the lung, known as primary lung cancers, are carcinomas. The two main types are small-cell lung carcinoma (SCLC) and non-small-cell lung carcinoma (NSCLC). The most common symptoms are coughing (including coughing up blood), weight loss, shortness of breath, and chest pains.

The vast majority (85%) of cases of lung cancer are due to long-term tobacco smoking. About 10–15% of cases occur in people who have never smoked.

Lung cancer kills usually by spread to vital organs such as lung and brain. This usually causes death when enough vital organ is compromised by cancer cells so it can no longer adequately function. Sometimes, there is not enough healthy lung tissue to allow you to absorb enough O₂ or get rid of CO₂.

Pneumoconiosis
An occupational lung disease. A restrictive lung disease caused by the inhalation of dust, often in mines and from agriculture.

In 2013 it resulted in 260,000 deaths including asbestosis and coal workers pneumoconiosis, or "BLACK LUNG". Inhaled dust is normally entrapped in the mucus blanket of the trachea and bronchi and rapidly removed from the lung by ciliary movement. However, some of the particles become impacted at alveolar ducts, where macrophages accumulate and engulf the trapped particulates. The pulmonary alveolar macrophage is a key cellular element in the initiation and perpetuation of lung injury and fibrosis. Unfortunately, the resulting scar tissue results in a lack of elasticity of the lungs. "Air trapping".