Respiratory Physiology

In-Lab Guide

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 FEV$_1$) 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.
STEP 1. Play with the Model of the lungs and diaphragm, and practice breathing!

Review "Pre-lab" material regarding ventilation and the respiratory pressures, volumes and muscles.

Make sure you know which muscles are involved in normal and forced ventilation. Make sure you know what occurs to the volume and pressure of the intra-thoracic space during inhalation and exhalation.

Q1. On a separate piece of paper, outline what occurs to the volume and pressure of the intra-thoracic space during inhalation and exhalation.

You may take a moment to play with the "bell jar model" of the lung if you’d like. It will not be on the exam.

The instructor demonstrates elasticity of lung tissue using a “sheep pluck”

In order to demonstrate the importance of elasticity and compliance of the lung tissue itself, we will be inflating a sheep’s lung.
**STEP 2.** Record and Study Respiratory Volumes and Capacities

### #1 Measuring Respiratory Volumes and Capacities using a “Turbine-type” Hand-Held Spirometer

Respiratory volumes, those volumes of air which are exchanged during pulmonary ventilation, are important indicators of the functioning of the respiratory system, and can be measured through the use of a spirometer.

**We have two styles of spirometer:**

1. **Wet Spirometer (Vitalometer):** Captures air in an inverted chamber the volume being indicated by the rise of the chamber in a bath of water. **See later step in which we calculate FEV1 for use of this machine.**

2. **Hand-held Spirometer:** this one has a turbine which rotates as air passes through it, and this rotation is geared down to drives the movement of a needle which indicates the volume of air.

**Hand-held “Proper” SPIROMETER OPERATION:**

1. **Attach a clean mouthpiece, and zero the instrument** by rotating the cover so that 0 cc is lined up with the needle. Our mouthpieces are disposable cardboard mouthpieces, unlike the one shown here.

2. **The subject should blow hard enough to move the needle,** but not so hard as to jam the instrument. The operator should monitor the free movement of the needle as the subject breathes.

3. **If the needle sticks,** try tilting the spirometer, tapping, etc., to insure its free operation.

Perform each of the following measurements three times and determine the average of each.

Throw the mouthpiece away after use.
Fill out the following graph using a “subject” selected in your group. Please remember that 1 milliliter (ml) = 1 cubic centimeter (cc). Notice the insert table showing you average residual volumes (you do not have to memorize these). We will be directly measuring 3 volumes, and calculating the 4th:

1. **Vital capacity (VC):** Set the dial to “zero”. Have the subject breath in as deeply as possible, then exhale “moderately hard” through the spirometer until no air remains in their lungs. Add the value to the graph.

   VC is the sum of tidal volume, inspirational volume and expiratory volume, and should equal the sum of the averages of the next three parameters. (Avg = 4800 cc). Perform the test three times, circle the largest of the three as your maximum vital capacity.

2. **Tidal volume (TV):** is the volume of air in easy, normal breathing. We will take an average, as it is difficult getting a person to do it correctly the first time. Read the “Trick” below. Set the dial to “zero”. Have the subject blow five easy breaths into the spirometer without resetting the dial, and dividing the total by 5. It is difficult to get the spirometer to work smoothly, but don’t give up. Add the value to the graph.

   (Avg = 500 cc).

   **TRICK:** the subject must blow a normal volume, but at a harder-than-normal force, so the needle will move. Try moving the spirometer away from the mouth as soon as the abdominal muscles begin to contract, which is a sign that the subject has gone “past tidal” and is forcing expiration.

3. **Expiratory reserve volume** is the volume of air that can be forced out after a normal breath has been exhaled. Set the dial to “zero”. Have the person breath in and out normally 5 times, noting that a normal breath is not very much volume. After the 5th “exhalation”, hold the spirometer up to the mouth and blow out all the air left in the lungs. Add the value to the graph.

4. **Inspiratory reserve volume** is the volume of air that can be forced in after a normal breath has been exhaled. It cannot be calculated directly using the hand-held spirometer, as it only measures air moving OUT. But, we can calculate it given the other measurements we have taken using this math (look at the graph while reading this equation):

   \[ \text{IRV} = \text{VC} - \text{TD} - \text{ERV} \]
You will be using a research-grade recording wet spirometer for this exercise. This consists of a wet spirometer with an attached rotating drum with pen for recording volume changes.

*Here is how the machine works. However, you will not be tested on this:*

A “Wet spirometer”, or vitalometer, is more accurate than the “turbine-type” used in STEP 1. As the subject blows air into a tube, it fills up a bell-shaped chamber immersed in water. Since air is lighter than water, the bell moves upward. We can measure the volume of air in the bell as it rises my simply measuring how high it rises! An attached rotating drum with pen records volume changes over time.

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

*If necessary, review the concepts discussed in the “Pre-lab”.*

The particular test you are doing today is a more valuable test in diagnostics than are simple lung volume and capacity measurements (static lung tests done with a spirometer) because it examines the rate or speed of exhalation (dynamic testing.) 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.

FEV₁ is a rapid but valuable test of lung function. Rate of airflow is volume/ time.

**THE INSTRUCTOR WILL ASSIST YOU.** There is a separate document regarding the use of the wet spirometer, and how to read the resulting graph using the laminated graph sheet, but you will not be tested on the material. However, it may help you review how to read the graph results.

You are asked to work in pairs or small groups, one of you being the subject and the other(s) acting as equipment operator and coach. The operator / coach will set the recording paper speed at its fastest setting just before the subject performs the vital capacity maneuver (inhales maximally and then exhales maximally.) At this rapid paper speed, the exhalation is expanded out so that you can analyze the data by looking at the slope of the curve. By referring to the graph, you can calculate the percent of the total vital capacity that is exhaled in the first (FEV₁)

**NOTE:**
FEV₁ should be (minimally) 75-80% of total (FVC). If it is less, it is indicative of some respiratory problem. Make sure you understand how to calculate a %!
**Q2.** Why do you suppose there is so much more inspiratory reserve than expiratory reserve? Think about just plain old anatomy.

**Q3.** In lecture, we described why residual volume exists. Explain it here in 2 ways: anatomical and functional (in other words, “why anatomically does it exist” and “why physiologically does it exist”).

**Q4.** On a separate piece of paper, draw a spirograph as shown. Label all the volumes and capacities that you can. Write down the averages for Tidal volume and Vital capacity.

**Q5.** Why are Vital Capacity and Residual Volume so variable? What do they depend on?

**Q6.** IRV = is the abbreviation for what? What should its value be (about?)

**Q7.** Define FEV₁ and FVC. **FEV₁ (reported) = ??** Also, what percentage should it be?

**Q8.** What is the difference between an obstructive and a restrictive respiratory illness?

**Q9.** What is the difference between a static and a dynamic respiratory test? Why do you think a restrictive respiratory illness shows up so quickly on a dynamic exam? In your answer, relate it to “elasticity”, please!
Q10. Look at the wet spirometer read-out below. What is this person's:

- VC?
- FEV₁ (measured)?
- FEV₁?

Q11. Using a "dashed line" on the above image, draw what you think the graph would look like if the person had an FEV₁ of 70%. Just do an approximation, do not worry about making the numbers work out.

How about 65%?
FVC, FEV₁, and their relation to Pulmonary Disorders

If necessary, review the concepts discussed in the “Pre-lab”. The following is a repeat of that section:

From the Pre-lab guide:

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.”