# **Lab 11: PULMONARY VENTILATION**

## **Pre-Lab Reading**

Respiration is the process by which the body obtains and utilizes oxygen and produces and eliminates carbon dioxide. It can be divided into 5 stages:

* Pulmonary ventilation, which is the movement of gases between the lungs and the environment. This will be studied in this chapter.
* Pulmonary gas exchange, which is the movement of gases between the lungs and the blood stream.
* Gas transport, which is the movement of gases within the blood stream.
* Tissue/blood gas exchange, which is the movement of gases between the bloodstream and the tissues.
* Cellular respiration, which is the consumption of oxygen and the production of carbon dioxide by cells and organelles.

The human respiratory system consists of a series of tubes that branch and terminate as clusters of small membranous air sacs called alveoli. During pulmonary gas exchange, oxygen and carbon dioxide cross between the alveoli and the capillaries by diffusion through the respiratory membranes. Factors that influence diffusion of the gases include surface area, diffusion distance, and concentration gradient.

Ventilation of the human lung is produced by muscular contraction. The resulting change in thoracic volume is conveyed to the elastic lungs by the fluid-filled pleural cavity. Inspiration is achieved by a contraction of the diaphragm and the external intercostal muscles, both of which increase the volume of the thoracic cavity. In the resting individual, expiration is usually passive since muscle relaxation and the elasticity of the lungs allow a decrease in thoracic volume.

The ventilation volume and ventilation rate are controlled by the respiratory control center, which is in the medulla oblongata of the brain. The center insures that the exchange of oxygen and carbon dioxide at the lungs takes place at a rate that matches the body's requirements. Respiratory control is a dynamic process, since the body's requirements change over time. This is the subject of the first activity, which examines breathing in a volunteer at rest and immediately after exercise. The respiratory control center in the medulla is responsible for matching the amount of O2 used by and CO2 produced at the tissues, with the amount of O2 taken up and CO2 discharged at the lungs.

Lung ventilation can be influenced by many factors, including emotion, speech, disease and the body's position relative to gravity.

## **Breathing Parameters at Rest and After Exercise**

The amount of air that moves in or out of the lungs during any one normal breathing cycle is called the tidal volume (TV). After normal inspiration, it is possible to breathe in additional air--this is called the inspiratory reserve volume (IRV). Similarly, after a normal expiration, it is possible to exhale additional air from the lungs--this is the expiratory reserve volume (ERV). Even if the expiratory reserve volume is fully expelled from the lungs, there is still a volume of air in the lungs, called the residual volume (RV), that cannot be exhaled. The residual volume has a very low oxygen and a high carbon dioxide concentration. But the residual volume is necessary to allow continuous diffusion of gases between the alveoli and the capillaries between breaths. Upon inhalation, fresh air mixes with stale air from the residual volume to create air in the alveoli that has gas concentrations that facilitate the diffusion of oxygen into and carbon dioxide out of the capillaries. The total amount of air that can be moved in one breath is the Vital Capacity (VC). The basic equation for vital capacity is (VC = TV + IRV + ERV)

The respiration center in the medulla insures that gas exchange at the lung matches the requirements of the body. During times of increased demand, the tidal volume can be increased, using some of the reserve lung volumes to bring more fresh air into the body. In addition, the rate of breathing and the rate of air movement in and out of the lungs can be adjusted. In this lab you will measure these parameters in a volunteer at rest and immediately after exercise, when the body's demands for oxygen have been elevated.

Pulmonary functions are described by the following respiratory volume definitions.

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| Tidal Volume (TV) | The volume of air inspired (or expired) during normal relaxed ventilation.  (Average = 500 ml in males and 400 ml in females)  10 – 20% of the vital capacity |
| Inspiration Reserve Volume (IRV) | The volume of air that may be forcibly inspired above the normal inspired tidal volume.  (Average = 3,000 ml)  60 – 70% of the vital capacity |
| Expiratory Reserve Volume (ERV) | The volume of air that may be forcibly inspired above the normal expired tidal volume.  (Average = 1,200 ml)  25% of the vital capacity |
| Vital Capacity (VC) | The volume of air expired from the maximal inspiration to maximal expiration or the volume of air inspired from maximal expiration to maximal inspiration.  VC = IRV + TV + ERV |
| Residual Volume (RV) | The volume of air remaining in the lungs following maximal forceful expiration.  (Average = 1,200 ml) |
| Total Lung Capacity (TLC) | The sum of the inspiratory reserve volume, tidal volume, expiratory reserve volume and residual volume  (Average = 6,000 ml)  TLC = IRV + TV + ERV + RV or TLC = VC + RV |
| Functional Residual Capacity (FRC) | The amount of air left in the lung after a normal expiration  FRC = RV + ERV or FRC = TLC - RV |

### **Spirometry to Measure Breathing Volumes**

A spirometer is a device used to measure lung volumes. A wet spirometer, so named because water is used to form a low friction seal between a bell float chamber and the environmental air can be used for this purpose. A simple dry spirometer is often used in a clinic or hospital to assess a patient’s respiratory function after surgery. We will be using a mouthpiece that measures air flow per time. This measurement is then converted to volumes and recorded by a computer program (IWorx). A Sanborn respirometer can be used to assess these values and to determine oxygen consumption by an individual.

These values can vary greatly and are affected by the ventilation habits of the subject and the position of the subject during measurement. Heavy breathing due to exercise usually decreases the IRV and increases the TV. The residual volume cannot be emptied from the lung of a healthy individual and thus cannot be measured directly with a spirometer.

Many breathing disorders can be detected by noting abnormalities in the volumes and capacities that we will be measuring in this lab activity. For example, a low Vital Capacity may indicate a loss of distensible lung tissue which could be caused by disorders such as pneumonia, pulmonary restrictions, bronchogenic carcinoma, or pulmonary congestion. Emphysema will cause the TV and FRC to increase and the IRV to decrease.