Understanding Pulmonary Function Testing

PFTs, Blood Gases and Oximetry

Skinny Little Reference Guide™

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INTRODUCTION

This brochure is intended to help you understand the meaning of Pulmonary Function Testing, commonly referred to as PFTs. The information found on these pages is not meant to provide specific medical advice, or to replace the continuing care, guidance and supervision provided by your physician and other members of your health care team. You should always seek proper medical advice and maintain regular communication with your physician.

Many tests and measurements can be used to gain information about your lung health including:

- Medical history
- Physical examination
- Chest CT and x-rays
- Arterial blood gases and oximetry
- PFTs
- Sputum culture
- Blood tests
- Bronchoscopy

While all of these tools are important in assessing your lung health, PFTs deserve special attention. That's because although PFTs are among the most familiar of all the lung tests, many of you report that they are also some of the most difficult tests to understand.

PFTs are a series of different breathing tests performed under the guidance of a trained pulmonary function technician, physician, or nurse and are typically done in a hospital or clinic setting. There are a variety of specific pulmonary function tests that may be ordered by your physician. Most of these breathing tests are done by blowing into a tube while sitting in a chair.

There are many things that can change the results in PFTs. These include not only the health of your lungs, but also the skill of the person testing you, your understanding and effort during the testing, differences in equipment, and differences in hospital or clinic procedures. The person coaching you through your testing will provide you with instructions before each test. If you don't understand these instructions, ask questions! For the best results, listen carefully and follow the coaching. Always ask for time to rest if you become tired.

GOOD ADVICE: Before your appointment you may receive specific instructions about how to prepare for the test, such as:

- Wear loose clothing, which will not restrict your ability to breathe deeply.
- Avoid large meals prior to your test time, which will make it more comfortable to breathe deeply.
- Do not use your inhaled medicines for some time before your testing

The American Thoracic Society (ATS) has issued guidelines for the performance of pulmonary function testing. The ATS stresses the need for maximum effort and consistency from you and provides standards for the accuracy of the testing equipment. Some people are concerned about the cleanliness of pulmonary function testing equipment. The ATS guidelines also specify cleaning and disinfection methods and schedules. In addition the equipment is cleaned and disinfected between patients according to the manufacturer's directions and clinic policy.

The following pages will describe the different breathing tests that are conducted as part of PFTs. These procedures range from simple "spirometry," which can be performed in a physician's office or a clinic, to more complex procedures such as measurement of "lung volumes" and "diffusing capacity" as well as other more sophisticated testing that must be performed in a pulmonary function laboratory, usually at a hospital. In addition, we will describe the importance of "arterial blood gases" and "pulse oximetry." We hope you find the material informative and helpful!

INTERPRETING THE RESULTS

A physician will interpret the results of your PFTs by comparing them to predicted normal values. Words such as mild, moderate, or severe may be used. Normal values are derived from research studies that include large numbers of non-smoking subjects with healthy lungs. Your lung function will

be compared to what is normal for a person your age, size, and sex. Height is important because taller people may have larger lungs. Men have larger lungs than women of the same height. As we get older, it is normal for lung function to decrease.

Often, the most important information gathered from pulmonary function testing is whether they have changed over time. For individuals with lung disease due to Alpha-1 Antitrypsin Deficiency, effective augmentation therapy is suggested by a stabilization of the diffusing capacity, as well as other measures described below.

Obstructive and restrictive are terms used to describe how the airflow and lung volumes are different from normal. Most lung diseases are labeled as either restrictive or obstructive. They are not names of actual lung diseases.

Emphysema (including emphysema associated with Alpha-1 Antitrypsin Deficiency), asthma, and chronic bronchitis are examples of chronic obstructive pulmonary disease (COPD); whereas, pulmonary fibrosis and asbestosis fall under the restrictive disease category.

PFTs are helpful when preparing for lung surgery, measuring effects of treatment on lung function, and determining the severity of disorders affecting the airways or other lung tissue.

A PFT may be repeated as often as your doctor thinks necessary. Lung problems or abnormalities can be checked for change by periodic pulmonary tests. A medical diagnosis is unlikely to be made from PFTs alone.

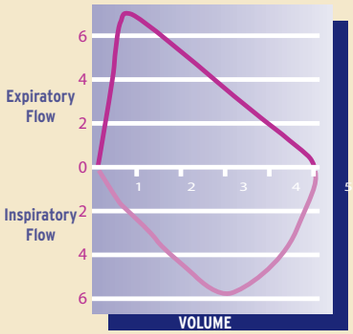
SPIROMETRY

Spirometry is the simplest and most widely available pulmonary function test. During a spirometry test you'll be asked to take as deep a breath in as you can and to blast it out as hard and long as you can. The spirometry-testing machine measures both the amount of air being exhaled and the time it takes to exhale that amount. The simplest of the spirometry tests simply measure the exhaled value; more sophisticated testing also measures the flow of air during inhalation. You will have your mouth wrapped around a mouthpiece of some sort during the test. This mouthpiece can be anything from a disposable cardboard tube to a rubber mouthpiece that fits tightly between your lips and teeth. You will be asked to wear a nose clip so that no air escapes though your nose. Often the spirometry test is repeated three times or more to be sure measurements are reliable and reproducible.

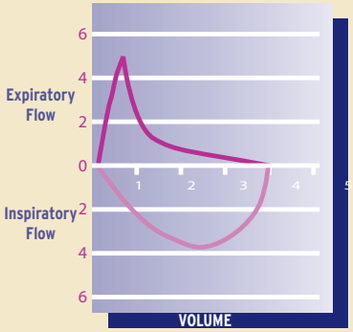
FIGURE 1

EXAMPLES OF FLOW-VOLUME LOOPS

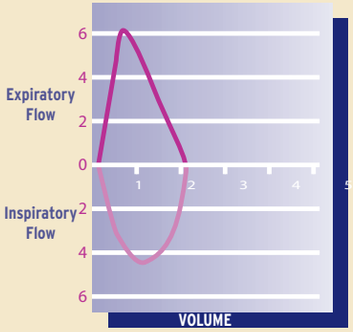
NORMAL



OBSTRUCTIVE



RESTRICTIVE



Horizontal line is the volume of air exhaled or inhaled

Vertical scale shows the flow-rate of air out (up) or in (down)

Your physician may order a bronchodilator to be given as part of spirometry. A bronchodilator is an inhaled medication that may dilate, or open up your airways. Spirometry is often done before and after the bronchodilator to show any response to medicine. Response to the bronchodilator may help your doctor determine what kind and how much, if any, airway disease you may have, and whether you need medication to improve your breathing.

Spirometry measures many different volumes (how much air is moved) and flow rates (how fast the air moves). Here are some of the more common spirometry measurements:

FORCED VITAL CAPACITY (FVC) is the volume of air exhaled from full inspiration to full expiration (top to bottom). You will be asked to breathe in as fully as you can and immediately blow out as hard and fast as you can until you feel you cannot blow any longer. You may be asked to forcefully inhale as well with each test. With computer assistance, the FVC effort may be used to create a line drawing called a "flow volume curve" or "flow volume loop." *(See Figure 1).*

FORCED EXPIRATORY VOLUME IN THE FIRST SECOND (FEV1) is the volume of air that you can forcefully blow out during the first second of the FVC. A decrease of the FEV1 compared to normal values (obtained from non-smoking, normal subjects your age, height and sex), may indicate a slowing of your flow rates. Chronic obstructive pulmonary diseases (COPD) such as emphysema (including emphysema associated with Alpha-1 Antitrypsin Deficiency), asthma, or chronic bronchitis can reduce flow rates.

RATIO OF FEV1 TO FVC (FEV1/FVC) is derived by dividing your actual FEV1 by your actual FVC and reporting the result as a percentage. In the normal adult, the ratio ranges from 70 to 85%, but decreases with age. This value can help determine what type of lung disease or damage, if any, has occurred. In obstructive lung diseases, such as emphysema, the FEV1/FVC ratio is lower than the normal range. In restrictive lung diseases, such as pulmonary fibrosis, or scar tissue build-up in the lungs, the ratio is usually normal or increased. Additional pulmonary function tests that measure lung volumes are helpful in defining a restrictive or obstructive process.

PEAK EXPIRATORY FLOW OR PEAK FLOW (PEF OR PF) is the fastest flow rate reached at any time during the FVC. It normally occurs near the beginning of your forced breath out. PEF is very dependent on your effort. PEF may also be reported as Forced Expiratory Flow Maximum (FEF Max).

MAXIMUM MID-EXPIRATORY FLOW (MMEF OR FEF25-75) is the flow rate in the middle of a breath out and is a very sensitive measure of airflow obstruction in those with mild disease.

If a pre- and post-bronchodilator study is done, the results of the tests listed above are compared before and after a breathing treatment. You will usually be asked to withhold any usual breathing treatments you take on a regular basis prior to such testing. By evaluating your improvement following a breathing treatment, the amount of reversible airway disease you might have can be assessed. When someone's spirometry shows obstruction to the flow of air on initial testing and that obstruction disappears and the spirometry becomes normal after a breathing treatment, this usually implies that the person has some form of asthma.

LUNG VOLUMES

To gain further information on your lung health, another group of tests your physician may order as part of pulmonary function testing are Lung Volumes. Below are brief descriptions of eight separate volumes of air, which are measured during lung volumes testing. *(See Figure 2)*.

TOTAL LUNG CAPACITY (TLC) is the maximum amount of air that your lungs can hold, measured at the very top of an inhalation.

VITAL CAPACITY (VC), also called Slow Vital Capacity (SVC), is the maximum amount of air that can be exhaled during a normal or slow exhalation after you have inhaled to your fullest (compared to the rapidly exhaled FVC, above).

FUNCTIONAL RESIDUAL CAPACITY (FRC) is the amount of air left in the lungs after a normal exhalation.

RESIDUAL VOLUME (RV) is the air remaining in the lungs after exhaling all the air you possibly can.

TIDAL VOLUME (VT) is the amount of air that is inhaled and exhaled with each breath. TV is the same as normal breathing when you are at rest.

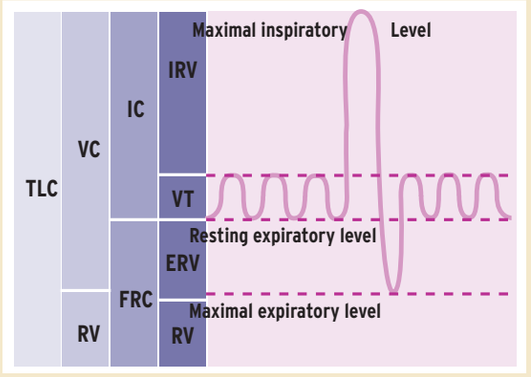
INSPIRATORY RESERVE VOLUME (IRV) is the greatest amount of extra air that can be inhaled after a normal inhalation.

INSPIRATORY CAPACITY (IC) is the maximum amount of air you can inhale after exhaling a normal breath.

EXPIRATORY RESERVE VOLUME (ERV) is the greatest amount of extra air that can be exhaled after a normal exhalation.

FIGURE 2

VARIOUS COMPONENTS OF LUNG VOLUME



OBSTRUCTIVE LUNG DISEASE USUALLY SHOWS:

- Increased TLC
- Increased RV
- Normal or decreased VC

RESTRICTIVE LUNG DISEASE MAY SHOW:

- Decreased TLC
- Decreased RV
- Decreased VC

IT'S A FACT: THE THREE MOST COMMONLY USED METHODS OF MEASURING THE LUNG VOLUMES ARE:

1. Nitrogen Washout – done by normal breathing of pure oxygen while exhaled gas is collected and analyzed for residual nitrogen
2. Helium Dilution – done by normal breathing of a gas mixture of helium and oxygen
3. Body Box (also known as plethysmography) – done sitting in an enclosed clear chamber while asked to perform a series of very small panting breaths (this is the most accurate lung volume measurement technique).

DIFFUSING CAPACITY (DLCO)

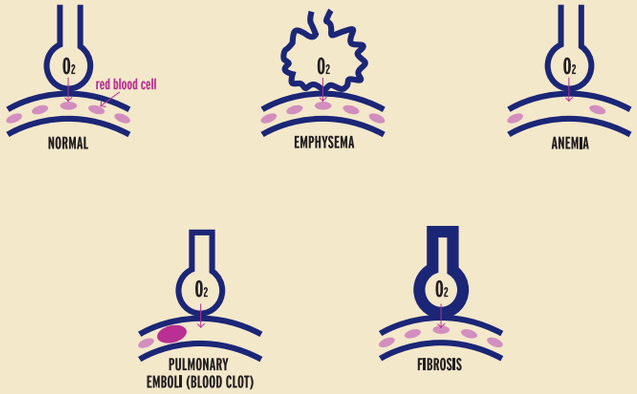
A third test that may be ordered part of the pulmonary function testing is the diffusing capacity (DLCO). Diffusing Capacity of the lungs measures how well gases such as oxygen (O_2) move from the lungs into the blood.

There are several different ways to measure the diffusing capacity but the most common is the ten-second single breath-hold technique. During this test, you are asked to take in a deep breath while keeping a mouthpiece in your mouth and wearing a nose clip. You are then asked to hold that breath for a minimum of 10 seconds. As you inhale, you are breathing a test mixture of gases that usually include an inert gas such as helium and a gas that mimics oxygen in the way it crosses into the blood and binds with red blood cells (carbon monoxide or CO). You are then asked to exhale and the machine takes a sample of the gases

you exhale. By comparing the inhaled gas concentrations with those you exhale, the computed results give a reading of how well oxygen moves from your air sacs into the blood. Results of this test can provide information to your physician about the amount of damage or abnormality that is present where the air and the blood meet in your air sacs or alveoli. *(See Figure 3)*. An increase (greater than predicted normal value) in the DLCO is rarely a concern.

FIGURE 3

CHANGES TO THE INTERFACE BETWEEN AIR SACKS AND BLOOD VESSELS IN VARIOUS LUNG CONDITIONS



DIG IN: THREE MAJOR FACTORS THAT DETERMINE DIFFUSION CAPACITY:

1. Amount of lung tissue that comes in contact with blood vessels (lung blood interface)
2. Thickness of the wall of the lung air sac (the thicker the wall, the lower the diffusing capacity)
3. Pressure difference between the gas in the air sacs and the gas in the blood.

Some disease conditions which may result in a lower than normal DLCO:

1. From decreased area for diffusion:
   - Pulmonary emphysema
   - Lung lobe removal
   - Lung tumor
   - Pulmonary emboli (blood clot)
   - Anemia
2. From increased thickness of the air sack wall:
   - Pulmonary Fibrosis
   - Asbestosis
   - Farmer's lung
   - Congestive heart failure

ARTERIAL BLOOD GASSES

Arterial blood gases (ABGs) give your physician even more information on your lung health. ABGs determine how well your lungs are getting oxygen into your blood and carbon dioxide out of your blood. A sample of blood is drawn from an artery, most often near the wrist. The most important measurements in the blood gas sample are acid base balance (pH), carbon dioxide ($PaCO_2$), oxygen (PaO_2), and oxygen saturation (SaO_2).

- pH is a measurement of the acid-base balance of the body. Although body fluids are mainly water, they do contain a mixture of acids and bases. A pH below 7.35 means acidosis (too much acid); above 7.45 means alkalosis (too much base). To function properly, your body should have a balanced pH. An increase in acid or base in the arterial blood can be caused by lung disease and/or by abnormalities in other organs of the body.
- $PaCO_2$ measures the amount of carbon dioxide dissolved in the arterial blood and is measured in units called millimeters of mercury (mm Hg). When CO_2 builds up in the blood, it is often an indication of severe lung disease.
- PaO_2 measures the actual amount of oxygen in the arterial blood and is also measured in millimeters of mercury (mmHg). This value decreases somewhat as we get older. A low PaO_2 may mean abnormal lung function.
- SaO_2 is a measure of the percent of hemoglobin molecules in your blood that are carrying oxygen.

BURNING ISSUE: At high altitudes, oxygen and saturation levels may decrease. During airline flights, these levels may also be affected.

PULSE OXIMETRY

A pulse oximeter is a device used to estimate the saturation of oxygen in the blood (SaO_2). This value is not as accurate as the arterial blood gas saturation and is best used as a guide for oxygen levels.

Normal values range from 93-100%. A probe clipped on your finger is the most common method of measurement. However, other sites such as your ear lobe may be used.

WHAT DO PFTS MEAN FOR YOU?

Keep in mind quality of life is not determined by the results of your tests. Each person is unique and many people live fulfilling lives with limited lung function. The key is to explore ways to keep or improve your quality of life.

Methods used to accomplish this may include:

- Exercise
- Breathing techniques
- Proper medications
- Equipment aids
- Social and emotional support

Pulmonary Rehabilitation programs and support groups are valuable sources of information. Develop a partnership with your physician. Good communication is essential, so don't be afraid to ask questions.

CROSS REFERENCE: A comprehensive guide to help you manage Alpha-1 Antitrypsin Deficiency can be found in the Big Fat Reference Guide™ at www.alphanet.org.

GLOSSARY OF TERMS

ALPHA-I ANTITRYPSIN DEFICIENCY - Genetic liver disease that may lead to emphysema at an early age (30's or 40's), but can affect all age groups.

ALVEOLI OR AIR SACS - Microscopic grape-like structures located at the very end of the airways of the lungs where gas exchange takes place.

AMERICAN THORACIC SOCIETY (ATS) - Medical society of physicians and other healthcare professionals dedicated to advancing the science of lung health; ATS establishes standards for performance of pulmonary function testing.

ANEMIA - Condition in which the number of red blood cells and the amount of hemoglobin in the blood is less than normal.

ARTERIAL BLOOD GASES (ABGS) - Sample of blood drawn from an artery, most often near the wrist, that measures the acid base balance (pH), carbon dioxide (PaCO2), oxygen (PaO2), and oxygen saturation (SaO2).

ASBESTOSIS - Restrictive lung disease that can develop after exposure to inhaled asbestos fibers. Asbestosis can cause scar tissue to surround the lungs.

BRONCHODILATOR - Medicine that dilates or opens up the airways in your lungs; may be given via nebulizer, inhaler, or oral pill.

CARBON DIOXIDE ($PaCO_2$) - Measurement of the carbon dioxide in the arterial blood. Carbon dioxide is a normal by-product of the body and is exhaled from the lungs.

CONGESTIVE HEART FAILURE (CHF) - Excessive fluid retention in the body due to weakness of the heart; can cause shortness of breath.

EMPHYSEMA - Obstructive airway disease in which the walls of the alveoli (air sacs) are damaged or destroyed.

FARMER'S LUNG - Restrictive lung disease developed from inhaled contaminants of wet hay or molds.

FLOW VOLUME CURVE OR LOOP - Graph plotting the flow (speed) and volume at which a patient exhales and inhales air during the FVC test.

OBSTRUCTIVE LUNG DISEASE/ COPD - Chronic disease that limits expiration; examples include emphysema, chronic bronchitis, and asthma.

OXYGEN (PaO2) - Measurement of the oxygen in arterial blood.

OXYGEN SATURATION (SaO2) - Percent of hemoglobin in red blood cells carrying oxygen.

PULMONARY - Medical term referring to lungs.

PULMONARY FIBROSIS - Restrictive lung disease in which scar tissue has formed in the lungs.

RED BLOOD CELL (RBC) - Blood cell that contains hemoglobin responsible for carrying oxygen in the blood.

RESTRICTIVE LUNG DISEASE - Disease that limits inspiration; examples include asbestosis, farmer's lung, and fibrosis.

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This brochure is produced by AlphaNet as part of its Alpha-1 Disease Management and Prevention (ADMAP) program.

AlphaNet is a not-for-profit organization providing disease management services and support to individuals affected by Alpha-1 through a staff of medical professionals and specially trained AlphaNet Patient Serivces Coordinators, available 24 hours a day, 7 days a week. To learn more about ADMAP or to find the AlphaNet Coordinator nearest you, visit our website (www.alphanet.org).