PULMONARY FUNCTION TESTS
A Workshop on Simple Spirometry & Flow Volume Loops

YOU SHOULD READ THE FOLLOWING MATERIAL BEFORE
Tuesday March 30 Interpretation of PFTs

Learning Objectives

1. Specify the indications for pulmonary function testing.
2. Be able to specify how spirometry is performed.
3. Describe what a spirometer measures and be able to define the following terms:
   - vital capacity (VC)
   - forced vital capacity (FVC)
   - forced expiratory volume in one second (FEV_1)
   - FEV_1 /FVC %
   - forced expiratory flow over 25-75% of FVC ($FEF_{25-75\%}$)
4. Distinguish between obstructive and restrictive patterns of ventilatory defect.
5. Define peak expiratory flow (PEF) and explain the benefits and drawbacks of its use in the clinical settings.

INDICATIONS FOR PULMONARY FUNCTION TESTING (PFT)
[adapted from H.W. Bonekat, U.C.Davis: http//medocs.ucdavis.edu/IMD/420C]

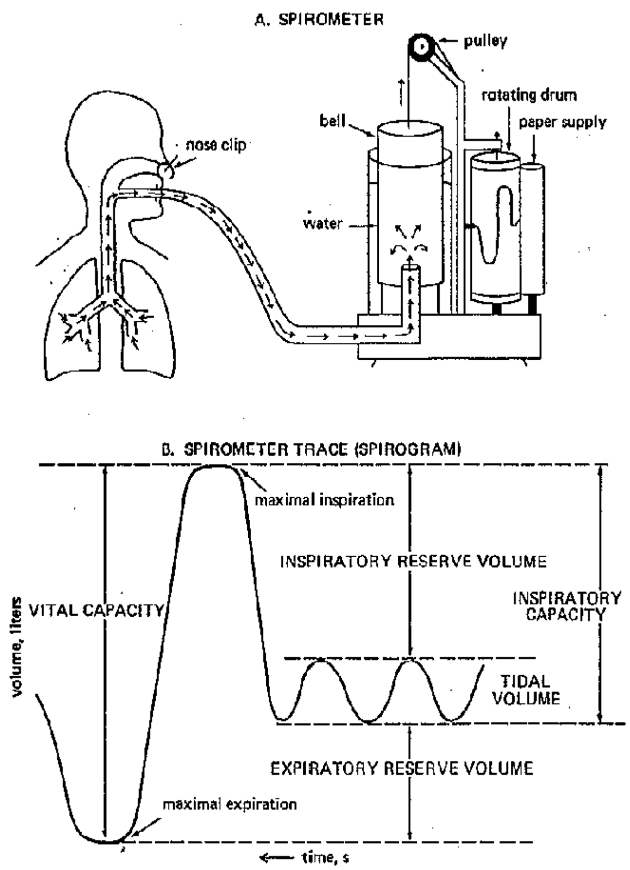
In a patient with suspected or known lung disease, a meticulous history and physical examination are essential. In addition, the physician needs help in differentiating among disease entities. Spirometry provides rapid and reproducible measurement of **lung volumes and flow rates** and it is routinely used as an objective method to assess functional changes in patients. The following are some of the more common reasons and examples for ordering PFT.

- **To evaluate patients with dyspnea, chronic cough or an abnormal chest x-ray (CXR).** Examples: A 70 year old man with mild dyspnea – is this due to a worsening of his emphysema or newly developing heart failure? Does the 17 year old high school student with persistent cough have functional disease or is this due to unrecognized asthma? A 60 year old man with heavy smoking history present with an abnormal CXR—does he have an underlying obstructive or restrictive lung disease or chest wall disease?
- **To quantify the severity of disease** Example: A 52-year-old woman with heavy smoking history presents with shortness of breath (SOB). On clinical examination, she has signs of underlying emphysema. PFTs are ordered to define the severity of her obstructive lung disease.

- **To screen for unsuspected, early or asymptomatic disease.** Example: A 22 year old university student and member of track team is being evaluated for episodes of wheezing which appear to be precipitated by his running. Does he have exercise-induced asthma?
- **To follow disease activity over time or in response to therapy.** Example: A 30-year-old man with history of sarcoidosis is being treated with prednisone. What is his response to therapy? Is he getting better or worse?
- **To predict the risk of surgery.** Example: You are asked to evaluate a 68-year-old man with lung cancer. The thoracic surgeon wants to perform a lung resection.
- **To assess response to bronchodilator medication.** Example: You are about to start a patient with asthma on beta agonist medication. After baseline PFTs you give the patient the bronchodilator medication and repeat the PFTs. You notice that the FEV_1 value improves 30% and the patient lets you know that he can breathe again and promptly donates $20,000 to the Hospital Fund Raising Campaign.
- **To quatitate impairment for disability evaluation.** Example: A man was involved in a fire inhalation accident at work 3 years ago. You are asked to evaluate this pulmonary impairment. PFT shows the individual has made dramatic recovery, as his pulmonary function values are near normal. You report your findings to the Workers' Compensation Board.
- **To document baseline or pre-clinical disease state for later comparison.** Examples: Occupational: A 34-year-old man needs baseline PFTs before working in a coal mine. Pre-Therapy: A 44-year old woman with newly diagnosed breast cancer needs baseline PFTs before undergoing chest irradiation.

SPIROMETRY

Spirometry is the most fundamental pulmonary function test that measures the volume of air inspired or expired as a function of time. It can monitor quiet breathing and thereby measure tidal volume. It can also trace deep inspiration and expiration and thereby provide information about vital capacity (VC). The VC is the total volume of air that can be exhaled after a full inspiration. The air remaining in the lungs after maximum expiration is the residual volume (RV). The Total Lung Capacity (TLC) is the sum of VC and RV and is the total volume of air within the lungs after a maximal inspiration. When a patient is asked to take a deep breath and blow it out as fast as possible this maneuver is called a Forced Vital Capacity (FVC). A similar maneuver done slowly is called a slow vital capacity (SVC).



Determination of lung volumes and capacities with a spirometer. A. Schematic representation of a water-filled spirometer. B. Determination of the tidal volume, vital capacity, inspiratory capacity, inspiratory reserve volume, and expiratory reserve volume from a spirometer trace.

Spirometry can not provide information about absolute lung volumes (TLC,FRC,RV) because it can not measure the amount of air in the lungs but only the amount entering or leaving the lungs. Techniques such as gas dilution and body plethysmography are used to determine absolute lung volumes.

Several types of spirometers can be used to measure volume of air by a bell, piston or bellows apparatus over time. Other spirometers depend on a flow detector (pneumotachometer) that integrates the measured flow into volume. Specific criteria and guidelines are outlined by the **American Thoracic Society,** before the data obtained is acceptable for interpretation. Results are displayed as a numerical listing of volumes, a graphic presentation of volume versus time or flow versus volume.

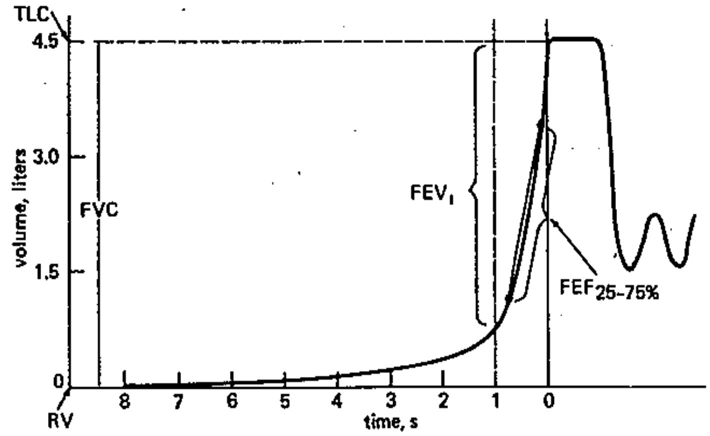
PERFORMING SPIROMETRY *"The performance of the spirometeric ballet is directly proportional to the doggedness of the technician." Heino, 1994.* PFT is a voluntary test. Therefore, a knowledgeable and persevering technician who is able to communicate fully with the patient is paramount in obtaining adequate spirometric data for interpretation. In performing the test, the patient should be seated comfortably. All tight clothing should be loose and dentures should be removed. The test should be explained carefully to the patient and demonstrated clearly by the technician. A mouthpiece is inserted making sure no leaks are present. The patient's nose is occluded with a properly fitted nose clip. The patient is instructed to breathe normally until a constant end tidal breath is established and the vital capacity maneuver initiated. After maximum inspiration is achieved, the patient is asked to blow air out as forcefully and rapidly as possible ('blast it out") and encouraged to "blow" "blow" " blow out" until he or she is unable to go on (a minimum of 10 seconds). If information regarding inspiratory flows is also required, the patient is asked at this point to forcefully inhale "suck it in" to a point of maximal inspiration. The maneuver is repeated until three acceptable and reproducible tracings are obtained.

MEASUREMENTS OBTAINED FROM THE SPIROGRAM

Measurements obtained from a spirogram in ATPS conditions (ambient temperature and pressure saturated with water vapor) are converted to and reported in BTPS (body temperature and pressure saturated water vapor). This is a done conventionally to correct for ambient differences in these variables under testing conditions.

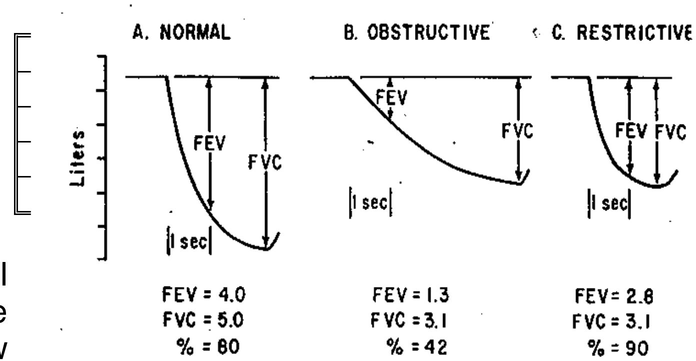
The size of a person's lungs depends on his or her height, age and sex. Population studies show that lung volumes correlate best with body height. Women usually have smaller lung volumes than men of the same height. Consequently, in a given subject, the observed spirometric volume can be analyzed in terms of the expected value based on height, age and sex. Several predicted equations are available based on population studies of non-smoking, healthy individuals. The observed values for the individual are expressed as percent of the predicted value (%predicted). . **It is important to note that the normal range of % predicted value for lung volumes among healthy individuals is about 100±20 % predicted.**

Two important measurements are obtained from the spirogram: FEV_1 and FVC. FEV_1 represents the forced expiratory volume in 1 second. The FEV_1/FVC ratio is calculated and helps differentiate between abnormal patterns of ventilatory defect. Other values, including $FEF_{25-75\%}$ (average flow during exhalation of the middle 50% of forced vital capacity) can also be calculated.

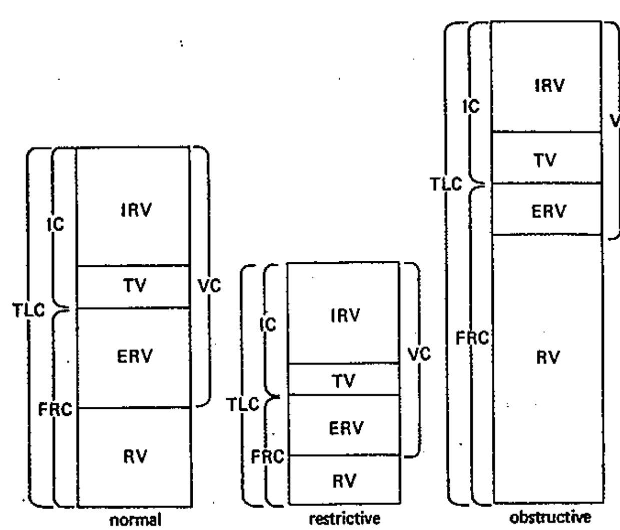


THE DIFFERENCE BETWEEN OBSTRUCTIVE AND RESTRICTIVE PATTERNS OF VENTILATORY DEFECT

Spirometric results are usually classified as normal or abnormal. Abnormal results are often subdivided into obstructive ventilatory defects, restrictive ventilatory defects and mixed ventilatory defects. Obstructive defects show a disproportionate reduction in expiratory airflow when compared to forced vital capacity. Therefore, individuals with obstructive ventilatory defect have a low FEV_1 and a low FEV_1/FVC ratio. Obstructive pattern of ventilatory defect is observed in patients with active asthma and chronic obstructive pulmonary disease (COPD). In general, the degree of obstruction is arbitrarily gauged as mild, moderate or severe in relation to the FEV_1/FVC ratio.

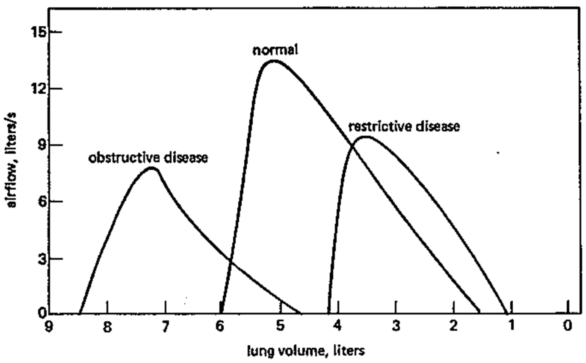


Individuals with restrictive ventilatory defect have reduced lung volumes and reduced FEV_1. However, there is no disproportionate reduction in FEV_1 when compared to FVC and the FEV_1/FVC ratio remains normal or even in some cases above normal due to the increased elastic recoil of the lungs. Restrictive ventilatory defect can be caused by a pulmonary deficit such as pulmonary fibrosis (abnormally stiff,



non-compliant lungs), or by a non-pulmonary deficit such as respiratory muscle weakness, paralysis, deformity or rigidity of the chest wall. Patients with mixed ventilatory defect have a reduction in both volumes and in airflow (reduced FEV_1/FVC) ratio. Mixed ventilatory defect is typical in patients with mixed lung disease such as COPD and fibrosis.

Maximal expiratory flow volume loops representative of obstructive and restrictive diseases.



The Peak Flow Meter is a simple device used often in asthma education programs to measure the peak expiratory flow (PEF). Day to day fluctuations in PEF activity can be monitored and serves as a guide for patients to adjust therapy or seek medical assistance.

The hallmark of obstructive ventilatory defect is a decrease in maximal expiratory flow rate. Expiratory flow rate can be measured as expired volume in the first second of an FVC maneuver (FEV_1), expired flow rate at it's peak (PEF) and at different lung volumes (e.g. FEF_{50}, FEF_{75}) or the average flow rate over the middle half of FVC maneuver ($FEF_{25\text{-}75\%}$). PEF is not a precise measurement and is highly dependent on the patient's effort. In contrast, FEV_1 is reproducible within a given individual. By the end of week 2 in this block, you should be able to answer why FEV_1 is considered a more reliable tool in quantifying a reduction in expiratory flow compared to PEF.

In general, both FEV_1 and forced expired flow rates are decreased in patients with obstructive ventilatory defect but the reduction in forced expiratory flow rates is often more striking. However, it is important to appreciate that the normal range for forced expiratory flow rates (FEF_{50}, FEF_{75}, $FEF_{25\text{-}75\%}$) among healthy individuals is very wide, 100±50% predicted.