Spirometry Basics

Pulmonary function tests (PFTs) are a series of different breathing tests led by a trained pulmonary function technologist, usually done at a hospital or clinic. To learn about your patient's lung health, you may want to have several pulmonary function tests done, including spirometry pre and post bronchodilator, lung volumes, diffusing capacity, airway resistance, and arterial blood gases.

What is Spirometry?

Spirometry measures how much air a patient can inhale and exhale as well as how fast they can exhale. It is an objective measurement for reversibility in asthma, a primary component in the diagnostic evaluation.

Key measurements obtained by spirometry are:

- (FVC) forced vital capacity: The largest amount of air that can be forcefully exhaled after a maximal inspiration. A decreased FVC may also indicate a restrictive pattern.
- (FEV_1): The forced expiratory volume in one second. The degree of obstruction is determined by changes in the FEV_1.(1)
- (FEV_1/FVC%): The forced expiratory volume in one second as a percent of the FVC. When the FEV_1 and FEV_1/FVC% are decreased, it is an indication of airway obstruction (80-85% is normal).

There may be other parameters measured during spirometry that are helpful in specific populations, such as pediatrics.

The National Heart, Lung, and Blood Institute (NHLBI) in the Expert Panel Report 2 "Guidelines for the Diagnosis and Management of Asthma" state that spirometry should be undertaken for patients in whom the diagnosis of asthma is being considered. The American Thoracic Society (ATS) and the American Association for Respiratory Care (AARC) have developed standards governing how to properly perform spirometry(2-4). These standards also provide guidelines on quality control measures and patient data acceptability (i.e., can you believe the results?). The NHLBI recommends following these standards when performing spirometry.

Who should be tested?

Spirometry is generally useful in individuals 4 years of age and older, although achievement of the ATS standards depends upon the stage of development of the individual. With a well-trained technologist, 95% of children 9 years or older are able to meet the adult criteria for spirometry as set forth in the ATS standards (5).

What should patients know about spirometry?

- Spirometry is a very common test to help you under stand your patient's asthma and to monitor control.
- Spirometry measures how fast they can exhale, as well as how much air they can inhale and exhale.
- Forced vital capacity (FVC) – During spirometry, the numeric and graphic results are measured and printed. The shape of the graph (flow-volume loop) is also helpful in the diagnostic evaluation.
- A decreased FEV_1/FVC% and response to bronchodilator is consistent with a diagnosis of asthma.
- Peak Expiratory Flow (PEF) or Peak Flow (PF) is the maximum flow achieved at the beginning of the FVC maneuver, but can be very patient effort dependent.
- The results of spirometry are dependent on good patient effort. Patients must be coached well in order to achieve an optimal test.
- A normal spirometry does not exclude asthma. Other tests may be needed to confirm or exclude the diagnosis.

How should patients prepare for their spirometry test?

- Wear loose clothing which will not restrict the ability to breathe deeply.
- Avoid large meals prior to the test time which will make it more comfortable for them to breathe deeply.
- Don't use bronchodilators four to six hours before testing, if possible.

How is spirometry different from peak expiratory flows?

Spirometry is the diagnostic tool recommended by the NHLBI in the diagnosis and management of asthma.

A peak expiratory flow (PEF) meter is a device recommended for monitoring changes in moderate to severe asthma. Peak flow only measures a change in the large airways. Other significant changes in the airways may occur that are detected by spirometry but not a peak flow meter.

How is spirometry performed?

1. After an explanation and a demonstration of proper technique, the patient takes a maximal deep breath. The patient then exhales forcefully and completely without hesitation for a prolonged period of time into a properly calibrated measuring device (pneumotach).
2. The patient should then repeat this maneuver until three acceptable efforts are obtained. This typically requires the patient to repeat the maneuver four to eight times.

When should testing be done with a bronchodilator?

A bronchodilator is required to assess reversibility of airflow obstruction. The medication is usually delivered using a small volume nebulizer. Correct delivery of the medication is important in adequately evaluating the response to the bronchodilator. An alternative for delivering the bronchodilator is using a metered dose inhaler (MDI) and holding chamber. If this method is used, an adequate number of puffs must be delivered and delivery technique should be carefully monitored.

If the patient is already on pulmonary medications, if possible they should be withheld for a certain length of time. Short-acting inhaled bronchodilators should be withheld for four to six hours before the spirometry is performed. Long-acting bronchodilators should be withheld for 24 hours. Anticholinergics are withheld six hours.

After waiting a minimum of 15 minutes post-treatment, the spirometry is performed once again. According to ATS guidelines, a positive response is at least a 12% increase and an absolute volume increase of 200 ml in FVC and/or FEV_1. Not all patients will respond to a bronchodilator in the initial assessment, but reversibility may be measured after the patient has been on a course of therapy for a period of time.

How do I know if the tests are accurate?

It is important to assess the acceptability of each maneuver based on ATS guidelines.

- **Step 1 – Assess the "end of test"**

To assess acceptability use the volume-time curve and the flow-volume loop (as illustrated below). The volume-time curve is used to assess "end of test". On the X axis, the maneuver must last at least **six seconds** and there must also be an obvious plateau for **at least one second**. It may require more than six seconds to achieve the one second plateau. This plateau is characterized by a "flat" section at the end of the exhalation. The flat section signifies that the patient has no more air to exhale. Young children may achieve a plateau prior to six seconds and this is considered acceptable.

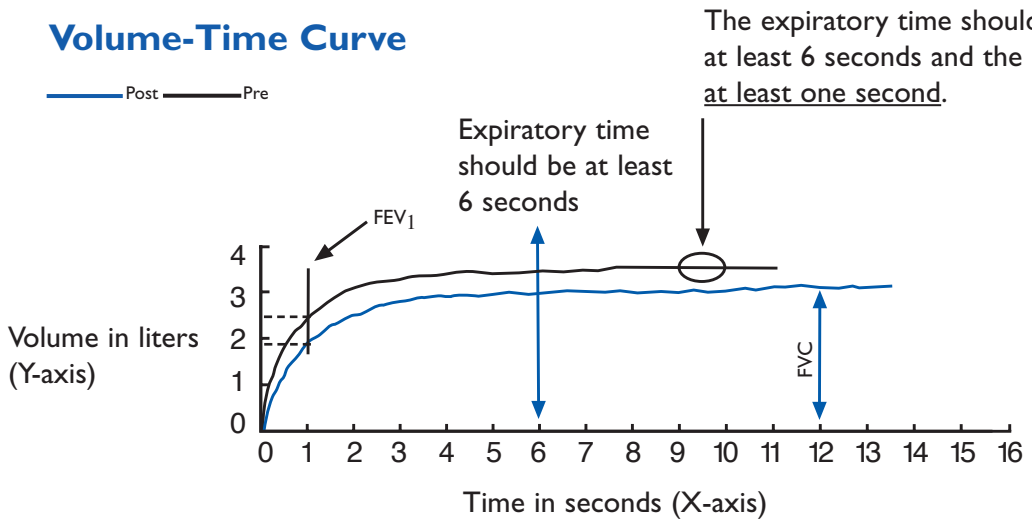
- **Step 2 – Assess the "start of test"**

Look at the expiratory side of the flow-volume loop and ensure that the initial portion of the graph is parallel to the Y axis, and there is a peak at the top of the curve. If the patient does not exhale forcefully and rapidly at the beginning of the maneuver, most modern spirometers will give you a back extrapolation error. If this occurs, the results are not valid.

- **Step 3 – Assess reproducibility**

FVC- The two best acceptable FVC efforts must be within 200 ml.

FEV_1- The two best acceptable FEV_1 efforts must be within 200 ml.



The expiratory time should be at least 6 seconds and the plateau at least one second.

The FVC is measured on the Y-axis of the graph in liters as shown on the graph.

The FEV_1 is also measured on the Y-axis in liters as shown on the graph.

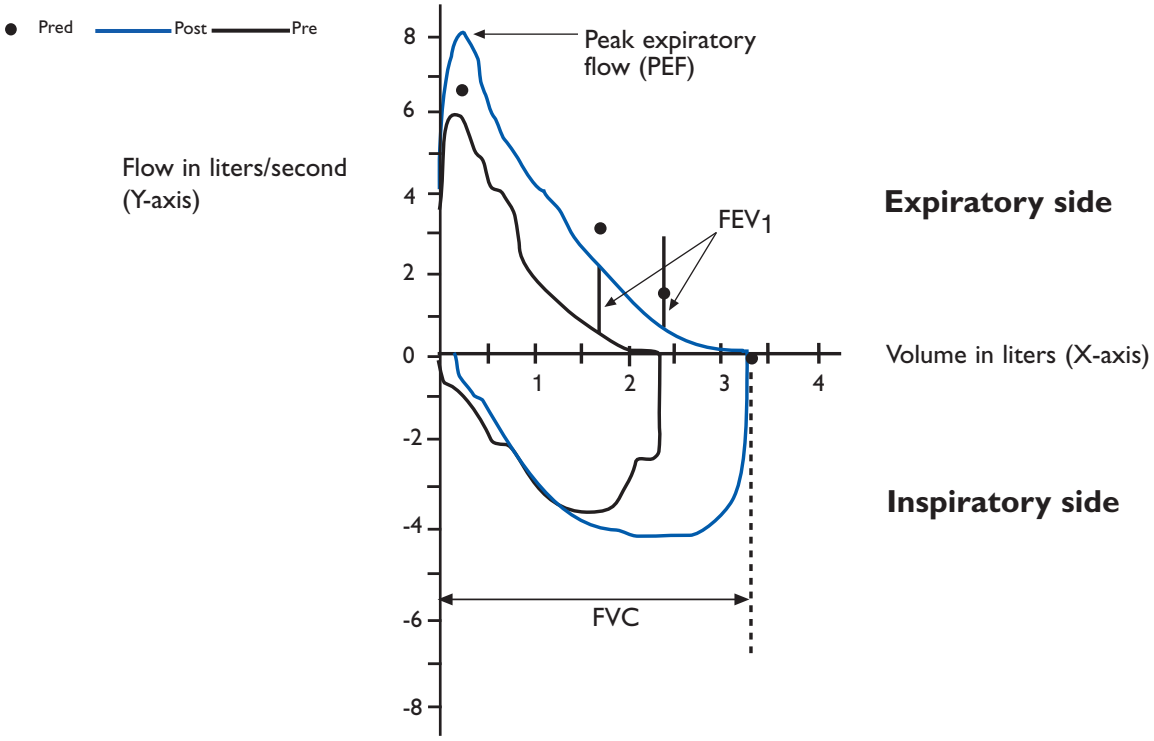
How do I use a flow-volume loop in assessment?

Review the flow-volume loop below. The initial portion of the curve should be parallel to the Y axis and there should be a sharp peak the top of the curve. The sharp peak indicates good patient effort.

Next, assess the shape of the expiratory side of the curve. The greater the degree of concavity, the more significant the obstruction. Post bronchodilator, the concavity is changed to a more convex shape.

The inspiratory effort should be done with just as much force as the expiratory maneuver, as illustrated in the graph below. If the tracing appears to want to "go past" the point where the patient originally started, it likely indicates the original inspiration was not as deep as it could be.

Flow-Volume Loop



What does actual patient data look like?

The following is actual patient data from the above flow volume loop and volume time curve. The patient is a 38 year-old female asthmatic with a good response to a bronchodilator.

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
----- SPIROMETRY -----						
FVC (L)	2.37	3.23	73	3.24	100	37
FEV1 (L)	1.66	2.65	62	2.46	93	48
FEV1/FVC (%)	70	82	85	76	93	8
FEF 25% (L/sec)	3.28			5.01		53
FEF 75% (L/sec)	0.38	1.40	27	0.60	43	59
FEF 25-75% (L/sec)	1.03	2.94	35	1.90	65	85
FEF Max (L/sec)	5.26	6.03	87	8.04	133	53
FIVC (L)	2.39			3.05		28
FIF Max (L/sec)	3.74			4.35		16

Other Pulmonary Function Tests (PFTs)

Lung Volumes

To differentiate between obstructing and restrictive patterns, lung volumes must be measured. The three most commonly used methods for measuring lung volumes are:

- **Body Box** – also known as plethysmography, is done while sitting in an enclosed clear chamber while asked to perform a series of very small panting breaths. This is the most accurate way to measure lung volumes.
- **Helium dilution** – done by normal breathing of gas mixture of helium and oxygen (may underestimate trapped gas in asthma).
- **Nitrogen Washout** – done by normal breathing of pure oxygen while exhaled gas is collected and analyzed (may underestimate trapped gas in asthma).

People with asthma may show changes in their lung volumes. This may help in the diagnosis and treatment of asthma.

Diffusing Capacity (DLCO)

Diffusing capacity of the lungs measures how well gases such as oxygen move from the lungs into the blood. The ATS accepted method is the single-breath technique. DLCO is generally normal or increased in asthma.

Airway Mechanics

This is an effort-independent test (spirometry is effort-dependent) that measures resistance to airflow in the airways between the mouth and the alveoli. Gentle panting breaths remove the bronchospastic component found in forced expiratory maneuvers. Changes in box pressure (plethysmograph) are proportional to alveolar volume changes. Airway mechanics are a more sensitive measure of changes in airway resistance caused by asthma, so therefore may detect airway disease earlier than spirometry and responses to therapeutic interventions.

Arterial Blood Gases (ABGs)

This is a blood test that can be done in order to show how well lungs are getting oxygen into the blood and carbon dioxide out of the blood. For this test, a sample of blood is drawn from the radial or brachial artery. Changes in arterial blood gases occur very late in an asthma exacerbation. When the PO_2 decreases and the PCO_2 increases it indicates impending respiratory failure.

REFERENCES

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4. American Association for Respiratory Care, Clinical practice guideline, Respir Care 1996; 41(7): 629-636.
5. Enright PL, et al, Quality of spirometry test performance in children and adolescents, Chest 2000; 118:665-671.