Review Renew a Florida Board of Respiratory Course

CE Credits

# Pulmonary Functions Testing

# Intro

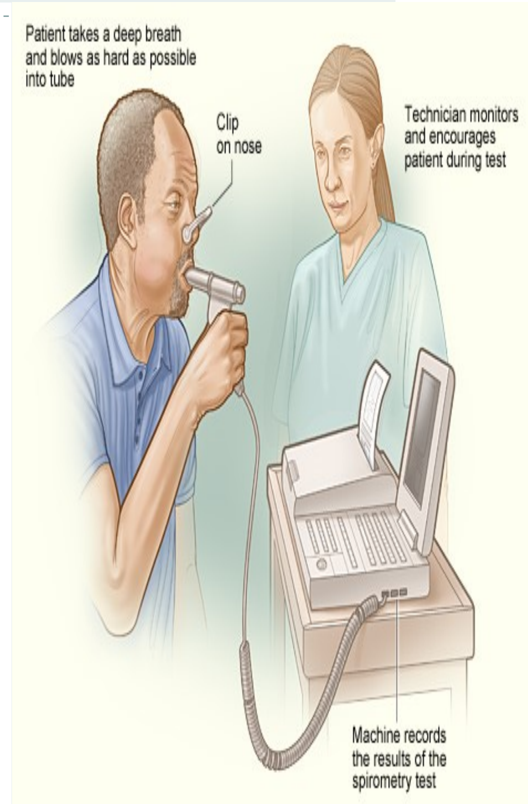
Practicing clinicians must stay familiar with pulmonary function testing because it is often used in clinical medicine for evaluating respiratory symptoms such as dyspnea and cough, measuring preoperative risk, and for diagnosing pulmonary diseases. This course is a Review of Concepts of Related to Pulmonary Function Tests.

***Pulmonary Function Tests*** **(PFTs) is a generic term used to indicate studies or maneuvers that may be performed using standardized equipment to measure lung function.**

PFTs can include simple screening spirometry, formal lung volume measurement, diffusing capacity for carbon monoxide, and arterial blood gases. These studies may collectively be referred to as a *complete pulmonary function survey*.

## BASIC CONCEPTS ☐

Basic concepts of normal pulmonary physiology that are involved in pulmonary function testing include mechanics (airflows and lung volumes), the ventilation-perfusion interrelationship, diffusion, gas exchange, and respiratory muscle strength. **Ventilation is the process of generating the forces necessary to move the appropriate volumes of air from the atmosphere to the alveoli to meet the metabolic needs of the body under a variety of conditions.** Simply, the contraction of the dia-phragm and other inspiratory muscles expands the thorax, generating negative pres-sure in the pleural space. One component of pleural pressure, known as *transpulmonary pressure,* causes a flow of air into the airways and lungs (inspiration). When the transpulmonary and alveolar pressures equilibrate, airflow stops, the inspiratory muscles relax, and the lungs and chest wall elastic recoil raise pleural pressure, forcing air out of the lungs (expiration).






- Define PFT
- Recall Ventilation—Basic Concept
- Identify Characteristics of Emphysema with Flow Volume Loop
- Understand the mechanisim of Brochoprovocation for Diagnosing Asthma
- δ the use of Spirometry Volumes
- ρ ρ

# Transmural Pressure

With a forced exhalation, the early portion of the spirometry maneuver is characterized by high flows, mostly from large airways, and the latter portion is characterized by low flows with a larger contribution from the smaller airways.[3] Forced inspiration is generally not flow limited and is a function of overall muscular effort. In contrast, a variety of factors affect expiratory flow, including the overall driving pressure, airway diameter, overall distensibility of the lungs and chest wall, dynamic airway collapse (from a flow-limiting segment), and muscular effort. The overall driving pressure is the pressure head at the alveolus, or $P_{ALV}$, which is the difference between pleural pressure ($P_{PL}$) and negative transpulmonary pressure ($P_{TP}$). So:

$$P_{ALV} = P_{PL} + P_{TP}$$

## MAXIMAL EXPIRATORY AIRFLOW

**The mechanism for the maximal expiratory airflow limitation seen in normal airways results from the gradual drop in pressure inside the conducting airways from the alveoli to the mouth, creating a transmural pressure gradient with the pleural pressure.** **This can cause dynamic airway compression and narrowing or closure of airways that have lost elastic recoil support from the lung parenchyma**.

## SPIROMETRY

**Spirometry is the most commonly used lung function screening study. It generally should be the clinician's first option, with other studies being reserved for specific indications.** Most patients can easily perform spirometry when coached by an appropriately trained technician or other health care provider. The test can be administered in the ambulatory setting, physician's office, emergency department, or inpatient setting. The indications for spirometry are diverse . It can be used for diagnosing and monitoring respiratory symptoms and disease, for preoperative risk stratification, and as a tool in epidemiologic and other research studies.

Spirometry requires a voluntary maneuver in which a seated patient inhales maximally from tidal respiration to total lung capacity and then rapidly exhales to the fullest extent until no further volume is exhaled at residual volume. The maneuver may be performed in a forceful manner to generate a forced vital capacity (FVC) or in a more relaxed manner to generate a slow vital capacity (SVC). In normal persons, the inspiratory vital capacity, the expiratory SVC, and expiratory FVC are essentially equal. However, in patients with obstructive small airways disease, the expiratory SVC is generally higher than the FVC. This difference might, however, be due partly to the difficulty in maintaining a *maximum* expiratory effort for an extended time period without experiencing dizziness or lightheadedness.


## FLOW VOLUME LOOP

The volume-time tracing and flow-volume loop ascertain the technical adequacy of a maneuver and therefore the quality of the data as well as identifying the anatomic location of airflow obstruction. **The volume-time tracing is most useful in assessing whether the end-of-test criteria have been met, whereas the flow-volume loop is most valuable in evaluating the start-of-test criteria. The technique of back-extrapolation of the start of the test to establish a zero time point on the volume-time tracing has been carefully defined and provides a uniform start point for timed measurements. It corrects for delayed or hesitant starts that might otherwise be mistaken for a falsely reduced $FEV_1$.** Standards for acceptability define limits for the degree of hesitation that can still yield an acceptable $FEV_1$. **The loss of elastic recoil characteristic of emphysema results in airflow limitation during the maximal exhalation that may be grossly underestimated if the patient applies less than maximal expiratory force**. Such efforts may still be deemed acceptable using the criteria of extrapolated volume. The time to peak flow appears to have excellent usefulness in identifying such efforts in this population (time to peak flow will be greater than 120 msec when effort is submaximal), but it is not yet a recommended acceptability criterion.

**The shape of the flow-volume loop can indicate the location of airflow limitation, such as the large upper airways or smaller distal airways. With common obstructive airflow disorders, such as asthma or emphysema, the disease generally affects the expiratory limb and can reduce the effort-dependent peak expiratory flow as well as subsequent airflows that are independent of effort. The descending limb of the expiratory loop is typically concave. In contrast, several unusual anatomic disorders that narrow the large airways can produce a variety of patterns of truncation or flattening of either one limb of the loop (variable upper airway obstruction) or both limbs of the loop (fixed upper airway obstruction).**

## BRONCHOPROVOCATION

When the baseline spirogram is relatively normal, inhalational challenge may be performed by aerosolizing progressive concentrations of methacholine by a dosimeter. This is typically performed as a five-stage procedure with five different increasing concentrations. After each stage, the patient performs a spirometry. When there is a 20% reduction in the $FEV_1$, the test is terminated and is considered positive for airway hyperreactivity. The provocative concentration dosage level of the inhalational agent required to produce a 20% reduction in the $FEV_1$ is labeled $PC_{20FEV1}$. If the drop in $FEV_1$ is less than 20% after five stages of this procedure, the challenge test is considered negative for airway hyperreactivity. A $PC_{20FEV1}$ of less than 8 mg/mL suggests clinically important airway hyperreactivity.

Bronchial hyperreactivity, as assessed by this inhalational challenge procedure, is very sensitive for the presence of active or current asthma. A positive test strongly suggests bronchial asthma. However, this test may be falsely positive in a variety of conditions, including chronic obstructive pulmonary disease, parenchymal respiratory disorders, congestive heart failure, recent upper respiratory tract infection, and allergic rhinitis.

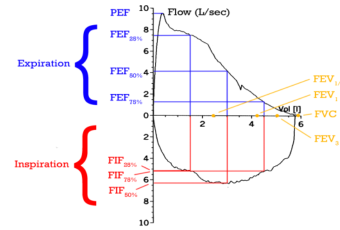
## BODY PLETHSMOGRAPHY

**Body plethysmography is an alterative method of measuring lung volume that takes advantage of the principle of Boyle's law, which states that the volume of gas at a constant temperature varies inversely with the pressure applied to it. The primary advantage of body plethysmography is that it can measure the total volume of air in the chest, including gas trapped in bullae. Another advantage is that this test can be performed quickly. Drawbacks include the complexity of the equipment as well as the need for a patient to sit in a small enclosed space. A patient is placed in a sitting position in a closed body box with a known volume. From the FRC, the patient pants with an open glottis against a closed shutter to produce changes in the box pressure proportionate to the volume of air in the chest. The volume measured by this technique is referred to as *thoracic gas volume* (TGV) and represents the lung volume at which the shutter was closed, typically FRC.**

**After the FRC is measured by any of these techniques, measurement of lung subdivisions (inspiratory capacity, expiratory reserve volume, vital capacity) ensues, ideally while the patient is still on the mouthpiece. From these volumes and capacities, the residual volume and total lung capacity can be calculated.**

## *Forced Expiratory Volume in 1 Second*

**FORCED VITAL CAPACITY**




**The $FEV_1$ is the most widely used parameter to measure the mechanical properties of the lungs.** In normal persons, the $FEV_1$ accounts for the greatest part of the exhaled volume from a spirometric maneuver and reflects mechanical properties of the large and the medium-sized airways. In a normal flow-volume loop, the $FEV_1$occurs at about 75% to 85% of the FVC.

$FEV_1$ is reduced disproportionately to the FVC, reducing the $FEV_1$/FVC ratio below the lower limit of normal.

FVC is a measure of lung volume and is usually reduced in diseases that cause the lungs to be smaller. Such processes are generally termed *restrictive* and can include disorders of the lung parenchyma, such as pulmonary fibrosis, or of the bellows, including kyphoscoliosis, neuromuscular disease, and pleural effusion. However, a reduction in FVC is not always due to reduced total volumes and can occur in the setting of large lungs hyperinflated due to severe airflow obstruction and air trapping, as in emphysema. In this setting, the FVC is decreased due to reduced airflow, air trapping, and increased residual volume, a phenomenon referred to as*pseudorestriction*. Reduced FVC can occur despite a normal or increased total lung volume. Therefore, FVC is not a reliable indicator of total lung capacity or restriction, especially in the setting of airflow obstruction. The overall accuracy of the FVC for restriction is about 60%.

## Obstructive & Restrictive

In a simplistic way, respiratory disease can be classified as *obstructive* or *restrictive* processes. Obstructive disorders, such as emphysema or asthma, are characterized by airflow limitation, have increased lung volumes with air trapping, and have normal or increased compliance (based on pressure volume profile). In contrast, restrictive disorders such as pulmonary fibrosis are characterized by reduced lung volumes and an increase in overall stiffness of the lungs (with reduced compliance).

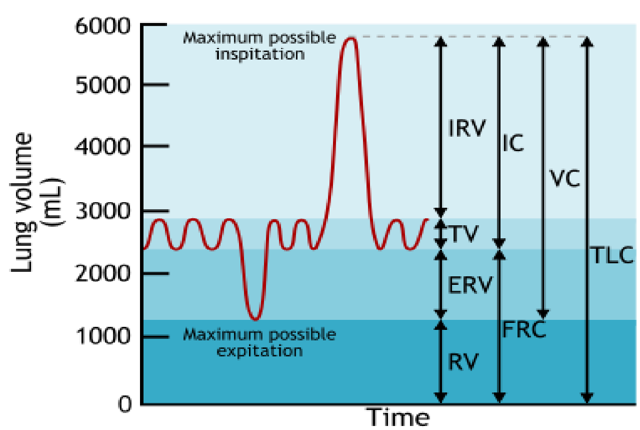
# GAS DILUTION

**Gas dilution techniques use either closed-circuit helium dilution or open-circuit nitrogen washout. They are based on the inhalation of a known concentration and volume of an inert tracer gas, such as helium, followed by equilibration of 7 to 10 minutes in the closed-circuit helium dilution technique.** The final exhaled helium concentration is diluted in proportion to the unknown volume of air in the patient's chest (residual volume). Usually, the patient is connected at the end-tidal position of the spirometer; therefore, the lung volume measured is FRC. .**In the nitrogen-washout technique, the patient breathes 100% oxygen, and all the nitrogen in the lungs is washed out. The exhaled volume and the nitrogen concentration in that volume are measured. The difference in nitrogen volume at the initial concentration and at the final exhaled concentration allows a calculation of intrathoracic volume, usually FRC.**

*Breathe through this! You're more than half way through this content!*

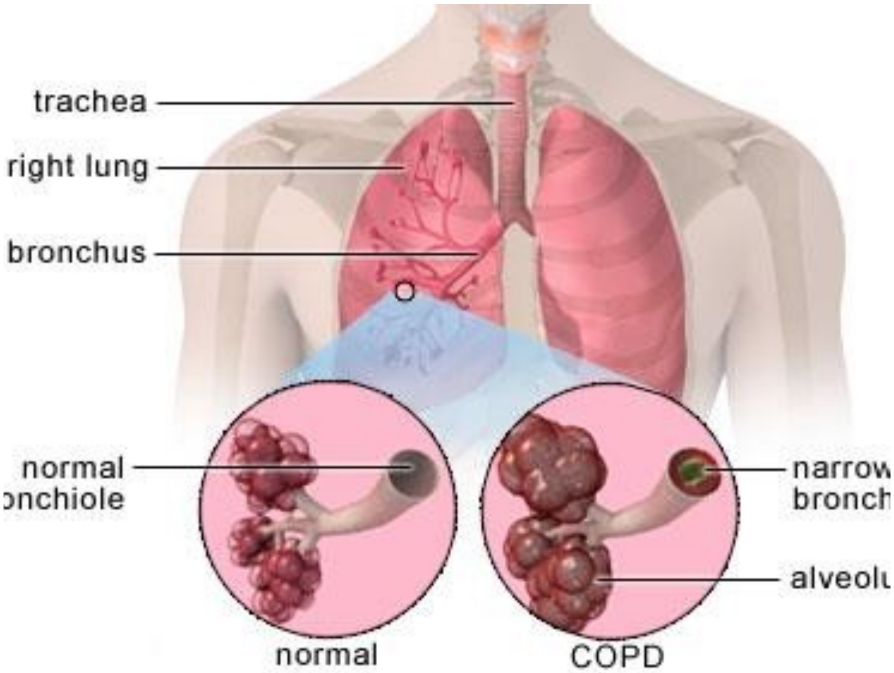
## SPIROMETRY— LUNG VOLUMES

Because spirometry is an expiratory maneuver, it measures exhaled volume or vital capacity but does not measure residual volume, functional residual capacity (resting lung volume), or total lung capacity.




Vital capacity is a simple measure of lung volume that is usually reduced in restrictive disorders; however, reduction in the vital capacity measured during spirometry should prompt measurement of lung volumes to confirm the presence or absence of a true restrictive ventilatory disorder.

Other pulmonary function methodology is required to formally measure total lung capacity, which is derived from the addition of functional residual capacity (FRC) to inspiratory capacity obtained from spirometry.. FRC is usually measured by a gas dilution technique or body plethysmography. Gas dilution techniques are based on a simple principle, are widely used, and provide a good measurement of all air in the lungs that communicates with the airways. A limitation of this technique is that it does not measure air in noncommunicating bullae, and therefore it can underestimate total lung capacity, especially in patients with severe emphysema.




| Common Restrictive and Obstructive Lung Diseases |
| --- |
| **Common Obstructive Lung Diseases** |
| Asthma |
| Asthmatic bronchitis |
| Chronic obstructive bronchitis |
| Chronic obstructive pulmonary disease (includes asthmatic bronchitis, chronic bronchitis, emphysema, and the overlap between them) |
| Cystic fibrosis |
| Emphysema |
| **Common Restrictive Lung Diseases** |
| Beryllium disease |
| Congestive heart failure |
| Idiopathic pulmonary fibrosis |
| Infectious inflammation (e.g., histoplasmosis, mycobacterium infection) |
| Interstitial pneumonitis |
| Neuromuscular diseases |
| Sarcoidosis |
| Thoracic deformities |

Chart From The Cleveland Clinic Foundation

OBSTRUCTIVE

RESTRICTIVE

MIXED

**Once the technical adequacy of the spirogram has been established, the next step is to classify whether the study is normal or has an obstructive pattern, a restrictive pattern, or a mixed obstructive and restrictive pattern. In general, the measured values are compared with the lower limits of normal predicted values from one of the published studies. Airflow obstruction exists, by definition, when the ratio of $FEV_1$ to FVC is below the lower limits of normal. When this ratio is above the lower limits of normal, obstruction is usually excluded. However, occasionally, early termination or short expiratory time can artifactually reduce FVC and falsely normalize the $FEV_1$/FVC ratio to mask obstruction.**

### Example of Criteria for Assessing the Severity of Abnormalities

### Normal

The test is interpreted as within normal limits if both the VC and the $FEV_1$/VC ratio are in the normal ranges.

Obstructive Abnormality

The test is interpreted as showing obstructive abnormality when the $FEV_1$/VC ratio is below the normal range.

**The severity of the abnormality might be graded as follows:**

May be a physiologic variant: Predicted $FEV_1$ ≥100%

Mild: Predicted $FEV_1$ <100% and ≥70%

Moderate: Predicted $FEV_1$ <70% and ≥60%

Moderately severe: Predicted $FEV_1$ <60% and ≥50%

Severe: Predicted $FEV_1$ <50% and ≥34%

### Restrictive Abnormality

The test is most reliably interpreted as showing restrictive abnormality on the basis of total lung capacity. If this total lung capacity not available, one may interpret a reduction in the VC without a reduction of the $FEV_1$/VC ratio as a restriction of the volume excursion of the lung. The severity of the abnormality might be graded as follows:

### Based on the TLC

Mild: Predicted TLC < LLN but ≥70%

Moderate: Predicted TLC <70% and ≥60%

Moderately severe: Predicted TLC <60%

### Based on Spirometry

Mild: Predicted VC < LLN but ≥70%

Moderate: Predicted VC <70% and ≥60%

Moderately severe: Predicted VC <60% and ≥50%

Severe: Predicted VC <50% and ≥34%

Very severe: Predicted VC <34%

Chart from the Cleveland Clinic Foundation

Diffusing capacity is a pulmonary function test that is commonly performed to help further characterize abnormalities in spirometry or lung volume measurements. The $D_LCO$ has greater degrees of variability between laboratories and requires some level of expertise to perform reliably.

Several processes can affect diffusing capacity. A pattern of diffusing capacity reduced proportionate to airflow obstruction (a proportionate reduction in $FEV_1$ and $D_LCO$) is typical for emphysema. A $D_LCO$ is reduced proportionately to a reduction in total lung capacity in the context of restrictive abnormalities suggests a parenchymal process such as pulmonary fibrosis. An isolated or disproportionate reduction in diffusing capacity along with either normal or fairly well preserved mechanics suggests predominantly a pulmonary vascular process such as primary pulmonary hypertension or thromboembolic disease.

Anemia or carboxyhemoglobinemia (from smoking) could affect the measured $D_LCO$.[10] The concept of a reduced $D_LCO$ that normalizes after correction for a lung volume measurement is often used to describe an extrathoracic or extraparenchymal disease process such as resection, obesity, or neuromuscular disease.[2] However, as noted previously, this approach has many limitations.

Review Renew CE
Florida Board of Respiratory
Care Provider: # 50-19961
Course # 20-602235
Email:
Cher@reviewrenewacls.com

# REFERENCES

1) The Cleveland Clinic Foundation

2) Mayo Clinic

3) Edgans Fundamentals of Respiratory Care