CARDIOPULMONARY PROCEDURES INFORMATION FOR REFERRING PROVIDERS

The following information is provided to assist SCH referring physicians who refer their patients to the Cardiopulmonary Laboratory for diagnostic cardiology or pulmonary testing.

Additional references are indicated for supplemental information.

The following information is presented to assist referring providers in the selection of a diagnostic test or to complement their interpretive baseline. SCH CPS technicians can provide additional procedure selection information or recommendations.

Pulmonary Function Testing –

- For the list of pulmonary function tests available through the Cardiopulmonary Laboratory, please refer to the brochure ___________________ distributed to the regional medical offices. For additional brochures, contact CPS at ______________. See below for information on the italicized selected procedures.
    - *Spirometry*
    - *Spirometry after Bronchodilator*
    - *Flow-Volume Loops*
    - *Helium Dilution Lung Volumes*
    - *Single Breath Diffusing Capacity (DLCO)*
    - *Body Plethysmographic Lung Volumes*
    - Arterial Blood Gases
    - Pulse Oximetry
    - Sputum Induction
    - *Maximal Inspiratory/Expiratory Pressures*
    - *Methacholine Challenge*

Some Indications for PFTs -

1. Screening for the presence of obstructive and restrictive diseases
2. Evaluating the patient prior to surgery - this is especially true of patients who:
    a. are older than 60-65 years of age
    b. are known to have pulmonary disease
    c. are obese (as in pathologically obese)
    d. have a history of smoking, cough or wheezing
    e. will be under anesthesia for a lengthy period of time
    f. are undergoing an abdominal or a thoracic operation

3. Documenting the progression of pulmonary disease - restrictive or obstructive
4. Documenting the effectiveness of therapeutic intervention
5. Evaluating the patient's condition for weaning from a ventilator.

Cardiac Function Testing -

- For the list of cardiac function tests available through the Cardiopulmonary Laboratory, please refer to the brochure ____________________ distributed to the regional medical offices. For additional brochures, contact CPS at _______________ See below for information on selected procedures.

Pulmonary Function Testing -

General information -

1. Complications of PFTs may include:
   a. faintness or light-headedness due to hyperventilation
   b. asthmatic episode precipitated by deep inhalation exercises
2. Situations in which PFTs may be contraindicated include, but are not limited to, the following:
   a. recent eye surgery, because of increased pressure inside the eyes during the procedure
   b. recent abdominal or chest surgery, because of potential interference with the ability to take deep breaths and stress on the surgical site
   c. chest pain, recent heart attack, or unstable cardiovascular status
   d. thoracic, abdominal, or cerebral aneurysm
   e. active tuberculosis or acute respiratory infection, such as a cold or the flu
   f. There may be other risks depending upon your specific medical condition. Be sure to discuss any concerns with your physician prior to the procedure.
3. Certain factors or conditions may interfere with the accuracy of PFTs. These factors may include, but are not limited to, the following:
   a. medications such as bronchodilators or pain medications (may affect the ability to perform the tests)
   b. pregnancy or gastric distention (may affect the ability to take in deep breaths)
   c. fatigue or other conditions that affect the ability to perform the tests

---

Spirometry

Spirometry is a measurement of forced expiration. The patient inhales maximally, filling his or her lungs to *Total Lung Capacity*, and then exhales forcefully into a device called a spirometer. The spirometer measures volume and time, and from this several important parameters may be calculated:

- FVC (Forced Vital Capacity): the maximum amount of air able to be exhaled on a single breath
- FEV_1 (Forced Expired Volume in 1 Second): the amount of air exhaled in the first second

- FEV_1/FVC: the percentage of the FVC exhaled in the first second

The last quantity (FEV_1/FVC) is particularly helpful in characterizing *airways obstruction*.

Spirometry after Bronchodilator
Spirometry, repeated after the administration of a bronchodilator (most often albuterol [*Ventolin, Proventil*]). Generally, an increase of more than 10% in either FVC or FEV_1 is considered a positive response.

Flow-Volume Loops
The same general test as spirometry, except the data collected are plotted in a different way, showing flow vs. volume. The patterns thus revealed may indicate the site and nature of any airways obstruction.

Helium Dilution Lung Volumes
This test measures the total amount of gas in the lungs after a complete inspiration. The patient is connected to a spirometer containing a known concentration of helium. Initially, the gas in the patient's lungs dilutes the helium present in the system, and the helium concentration falls rapidly. After a few minutes, however, the patient and the spirometer equilibrate, and the helium concentration reaches a steady value. By measuring the initial and final concentrations of helium present, and by knowing the volume of the spirometer, the amount of gas in the patient's lung at the start of the test may be calculated.

Single Breath Diffusing Capacity
The single breath diffusing capacity, or DLCO, is a measure of the ability of the lungs to diffuse oxygen into, and carbon dioxide from, the bloodstream. The test is performed by having the patient complete the following steps:

1. expire all the way to *Residual Volume*
2. inspire all the way to *Total Lung Capacity*, breathing from a supply of test gas
3. hold breath for ten seconds
4. expire forcefully

The concentrations of certain gases present in the "test gas" is measured prior to the test. The initial portion of the final expirate is discarded, and a portion of the remainder is analyzed. Generally, the difference between the concentrations present before the breathhold and after the breathhold indicates the amount of gas that diffuses through the lungs and into the bloodstream.

Body Plethysmographic Lung Volumes
This test measures the same things as does Helium Dilution Lung Volumes, but in a very different way. The patient sits in a clear rigid chamber, breathing through a valve. At

some point in the breathing cycle, the valve is closed for a few seconds and the patient is asked to pant (although no breathing will occur since the valve is closed). Each time the patient tries to pant out, the gas in the lungs is decompressed slightly and the gas in the box surrounding the patient is compressed slightly. When the patient tries to pant in, the opposite occurs. By measuring the pressure changes in the lungs and in the box, the amount of gas in the patient's lungs may be calculated.

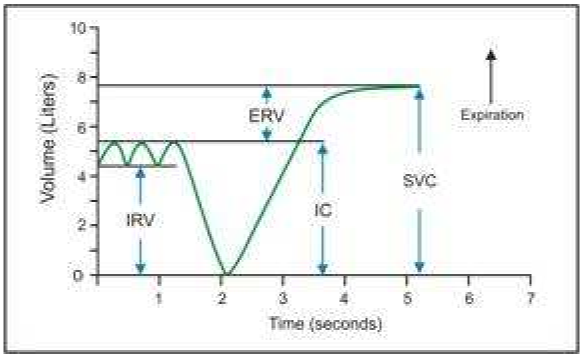
Pulmonary Exercise Test
Any one of a family of tests in which measurements are made while a patient is asked to perform increasing amounts of exercise.
In the simplest type of exercise test performed in our laboratory, a *desaturation* test, measurements of heart rate and oxygen saturation from pulse oximetry are recorded while the patient is asked to pedal a stationary bicycle. The bicycle's resistance is increased as the test progresses and the patient is asked to continue until either the patient's oxygen levels fall or until the patient is unable to continue. If the test is ended due to a fall in oxygen levels then it is repeated, after an appropriate rest and recovery period, while the patient is given extra oxygen via a nasal cannula (a small oxygen tube placed beneath the nose). This cycle continues until the patient is able to exercise to exhaustion without a fall in oxygen levels or until the maximum amount of supplemental oxygen has been used. This test is used primarily to detect and quantify the need for supplemental oxygen.

Methacholine Challenge
In a *Methacholine Challenge*, a patient performs repeated spirometry tests following inhalation of increasing concentrations of the chemical methacholine. In some patients with *hyperreactive airways*, methacholine may cause a change in airways function which is detected by the spirometry testing. Those patients with a significant change in spirometry following inhalation of methacholine will have a positive test result. Following this test, patients are given *albuterol*, a drug which counteracts the effects of the methacholine. This test may be helpful in evaluating unexplained cough or possible asthma.

Maximal Inspiratory/Expiratory Pressures
This is a test of total respiratory muscle strength. In one part of the test, the patient is asked to attempt to inhale as forcefully as possible against a blocked tube. In the other part of the test, the patient is asked to attempt to exhale as forcefully as possible against a blocked tube. In both cases, the pressure the patient generates while attempting to inhale or exhale is recorded. This pressure is correlated with the overall strength of the breathing muscles and may be helpful in assessing possible respiratory muscle weakness.

Slow Vital Capacity

Slow vital capacity was arguably the first ever recorded lung volume. The full excursion of the maneuver gives a measure of the change in volume of gas in the lungs from complete inspiration to complete expiration or vice versa. The recording of volume versus time is called a spirogram. In the example shown, the recording begins with the subject quietly breathing in a steady-state condition followed by a maximal breath-in and a full breath-out. The spirogram of a slow vital capacity maneuver has several key identifying components:



Identifying the Sub-divisions of Slow Vital Capacity

Slow Vital Capacity (SVC) is the maximum volume of air which can be exhaled or inspired in a slow/steady maneuver.

Vital Capacity (VC) is the largest of the volumes from either a forced (FVC) or a slow (SVC) maneuver.

Expiratory Reserve Volume (ERV) is the maximum volume of additional air that can be expired from the end of a normal expiration.

Inspiratory Capacity (IC) is the maximum volume of air that can be inspired from end expiratory position. Called a capacity because it is the sum of 2 lung volumes: IC = IRV+TV

Forced Vital Capacity (Dynamic)

Flow volume loops are perhaps the most recognizable of all pulmonary function tests. The shape of the curves are extremely diagnostic but the very nature of the effort required to reproduce the shape (loop) means that often data is of a poor quality. Each of the test efforts is automatically reviewed against ATS standards and furthermore a "confidence" rating is applied by an even stricter performance scan utilizing Morgan Scientific experience.
In most pulmonary function labs, flow volume loops are usually the first tests gathered from the spirometry testing. By examining the information and shape of the loop, it helps clinicians further understand the way air is moving into and out of the lungs and help identify specific diseases that can otherwise be very hard to diagnose.

From the information gathered with this test certain deductions about what is happening throughout the lung can be made. In particular we comment on obstructive lung disorders and degree of the disease. Obstructive lung disease is simply put, a problem with the airways that do not allow airflow to move smoothly from the alveoli (air sacs of the lungs) and smallest airways out through the trachea (main windpipe) and ultimately out through the mouth when exhaling or inhaling. There are a number of common processes that can lead to this kind of a problem including emphysema, asthma and chronic bronchitis.

The results of dynamic PFT tests place patients in 1 of 3 categories:

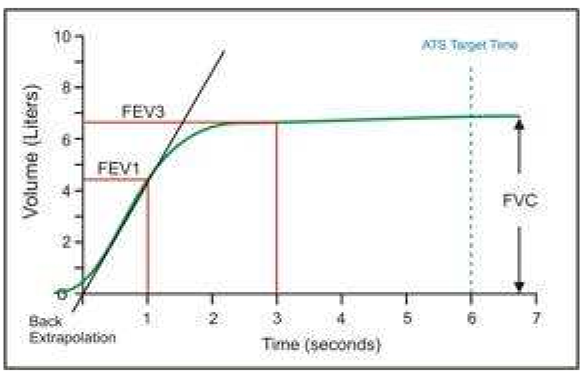
- normal lung function
- obstructive disease
- or restrictive disease

In obstructive lung disease, patients have decreased airflow (decreased FEV1/FVC ratio) and usually have normal or above-normal lung volumes.

In restrictive lung disease, patients have decreased lung volumes or TLC with normal airflow (normal FEV1/FVC ratio but with reduced values for both FVC and FEV1 individually).

For many years, the forced expiratory effort was only represented as a plot of volume against time.

Identifying Measurements on the Forced Expiratory Maneuver



Forced Vital Capacity (FVC) is the maximum volume of air which can be exhaled or inspired during a forced (FVC) maneuver. For the tests to be of significance, it is recommended that the forced effort be 6 seconds or longer in duration.

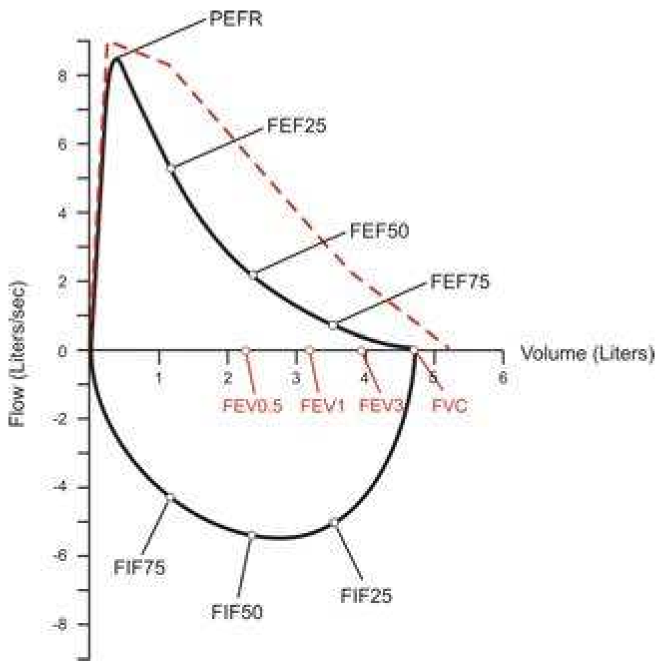
In most cases, the SVC is always greater than FVC. As more obstruction is present in the lungs the difference between SVC and FVC is more pronounced.

Forced Expired Volume in one second (**FEV1)** is the volume expired in the first second of maximal expiration after a full inspiration and is a useful measure of how quickly the lungs can be emptied.

FEV1/FVC is the FEV1 expressed as a percentage of the FVC and gives a clinically useful index of airflow limitation.

The forced volume excursion when plotted against flow rate reveals perhaps the most recognizable shape in pulmonary function testing. There are many measurements that can be taken from this single dynamic effort:

Identifying Measurements on the Flow Volume Loop



Peak Expiratory Flow Rate (PEFR). The first landmark reached is the PEFR. The first blast of air exhaled from the patient reaches this flow rate almost immediately. The flow rate then quickly slows as more air is exhaled. This landmark is very important in judging if the patient is giving maximal effort, overall quality of the test, strength of expiratory muscles, and the condition of the large airways, such as the trachea and main bronchi.

Forced Expiratory Volume after 0.5 seconds (FEV0.5). The FEV0.5 indicates the amount of air exhaled with maximum effort in half a second.

Forced Expiratory Volume after 1 second (FEV1). The FEV1 indicates the amount of air exhaled with maximum effort in the first second. The FEV1 is another very important landmark in assessing the overall status of the patient and quality of the test. This test result is also important in pre- and post-bronchodilator tests in determining the effects of bronchodilators on the airways.

Forced Expiratory Volume after 3 seconds (FEV3). The FEV3 indicates the amount of air exhaled with maximum effort in the first three seconds.

Forced Expiratory Volume after 6 seconds (FEV6). The FEV6 indicates the amount of air exhaled with maximum effort in the first six seconds. This parameter is primarily used to ensure expiratory efforts meet or exceed 6 seconds.

Forced Vital Capacity (FVC). Another important result of a Flow Volume Loop is the FVC. Many of the other results depend on this number. The FVC is the total volume of air exhaled with maximal effort.

Forced Expiratory Flow at 25% of FVC (FEF25%). The FEF25% is the flow rate at the 25% point of the total volume (FVC) exhaled. Assuming maximal effort this flow rate is still indicative of the condition of fairly large to medium size bronchi. This landmark is used in calculations with the FEF75% to give FEF25-75%, the middle half of the FVC, which many physicians look at as not being dependent on patient effort and an indicator for obstruction in the small airways. This value is very dependent on the total volume exhaled (FVC) and tends to be highly variable from test to test.

Forced Expiratory Flow at 50% of FVC (FEF50%). The FEF50% is the flow rate at the 50% point of the total volume (FVC) exhaled. This landmark is at the midpoint of the FVC and indicates the status of medium to small airways, it's sometimes looked at instead of the FEF25-75%.

Forced Expiratory Flow at 75% of FVC (FEF75%). The FEF75% is the flow rate at the 75% point of the total volume (FVC) exhaled. This landmark indicates the status of small airways and is used in the FEF25-75% calculation. The damage done by most chronic pulmonary diseases show up in the smallest airways first and early indications of this damage begin to appear toward the end of the expiratory part of the Flow Volume Loop.

Forced Inspiratory Flow at 25% of FVC (FIF25%). The FIF25% is the flow rate at the 25% point on the total volume inhaled. The inspiratory flow rates are relatively unimportant in assessing the asthmatic. Abnormalities here are indicators of upper airway obstructions. Areas of the mouth, upper and lower pharynx (back of the throat), larynx (voice box), and vocal-cords impact the inspiratory flow rates.

Peak Inspiratory Flow Rate (PIFR). The fastest flow rate achieved during inspiration.

Forced Inspiratory Flow at 50% of FVC (FIF50%). The FIF50% is the flow rate at the 50% point on the total volume inhaled.

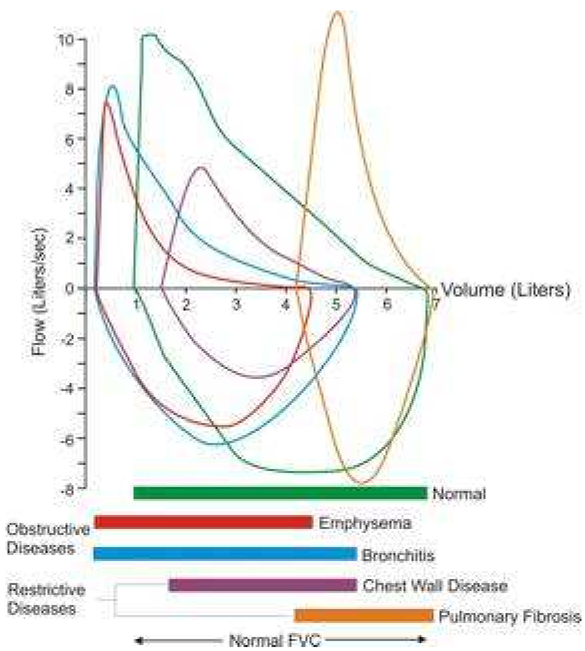
Forced Inspiratory Flow at 75% of FVC (FIF75%). The FIF75% is the flow rate at the 75% point on the total volume inhaled.

Some of the other numbers that can be calculated from the Flow Volume Loop are:

FEV1/FVC%, and FEV3/FVC% - These are ratios calculated by dividing the Forced Expiratory Volume results by the Forced Vital Capacity and expressed as a percentage of the FVC.

Forced Expiratory Time (FET) - The time it takes to exhale as much air as possible. To obtain reliable FVC values, the expiratory effort should be continued for at least 6 seconds. The FET should never be less than 6 seconds unless the patient is severely restricted.

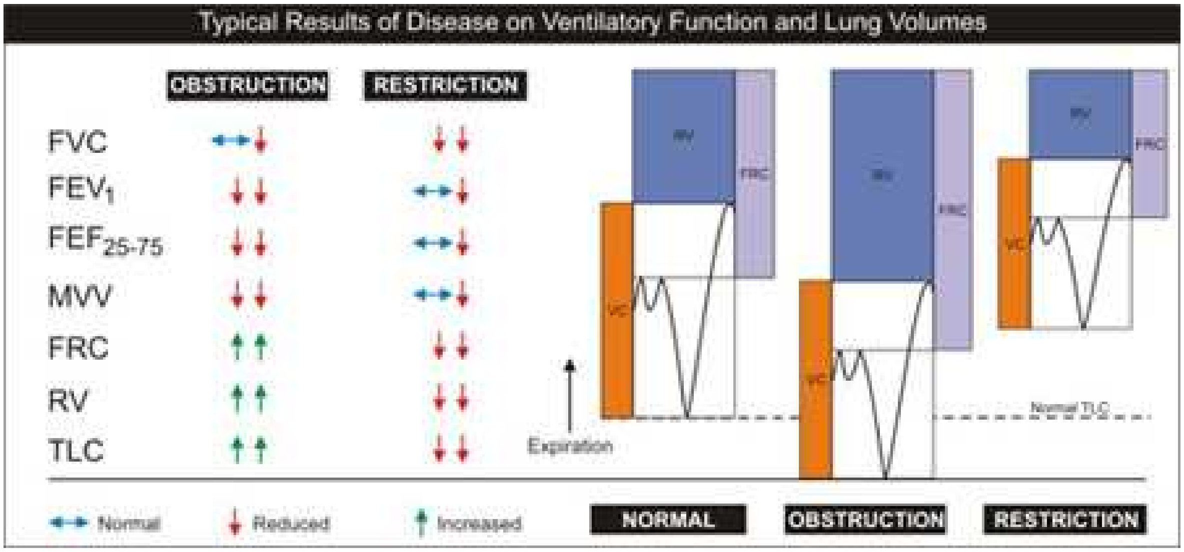
The illustration below shows the variety of flow volume loop shapes that often relate to particular disease. When looked at in relation to the lung volume further clinical information can be revealed.



Maximum Voluntary Ventilation (Dynamic)

The volume of gas that can be breathed in 15 seconds when a person breathes as deeply and quickly as possible. Also called *maximum breathing capacity*. The result is extrapolated from 15 seconds to show what could be achieved over one minute. As a general guide, the value should correlate closely to the FEV1 x 35.
This test is usually performed whenever spirometry is done. If people have weakness in the muscle of breathing this test can help identify these difficulties. The MVV is a test of ultimate effort dependency and is often discarded by physicians. Since it has been shown that the FEV1 x 35 is a good indication of MVV, many centers simply report that result. Disability criteria however still require an actual MVV to be done!

Typical Results of Disease on Spirometry



Lung Volumes

Understanding and identifying the lung volume components is essential in pulmonary function testing.

Measurements of lung volumes are important to confirm or clarify the nature of lung disorders. The flow volume loop may indicate an obstructive or restrictive or obstructive/restrictive pattern, but a further test of lung volume is often necessary for clarification.

In an obstructive lung disease, airway obstruction causes an increase in resistance. During normal breathing, the pressure volume relationship is no different from a normal lung. However, when breathing rapidly, greater pressure is needed to overcome the resistance to flow, and the volume of each breath gets smaller. The increase in the effort to breathe can cause an overdistention of the lungs.

The flow volume loop may show lower than normal FEV1 and FEF25-75, but it is not until a lung volume has been determined that an increase in TLC, FRC and RV can be confirmed.

Common obstructive disease include asthma, bronchitis and emphysema.

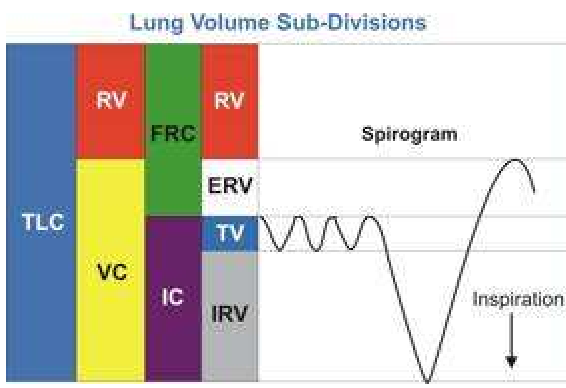
In a restrictive lung disease, the compliance of the lung is reduced which increases the stiffness of the lung and limits expansion. In these cases, a greater pressure than normal is required to give the same increase in volume.

The flow volume loop may show lower than normal FVC, but the FEV1 and FEF25-75 may only be mildly effected. The lung volume measurement will clearly show a reduction in TLC, FRC and RV.

Common causes of decreased lung compliance are pulmonary fibrosis, pneumonia and pulmonary edema. Patients whose respiratory muscles are unable to perform normally because of a neuromuscular disease or paralysis can show a restrictive pattern.

The total volume contained in the lung at the end of a maximal inspiration is subdivided into volumes and also into capacities.

There are four lung volume subdivisions which:
a) do not overlap.
b) can not be further divided.
c) when added together equal total lung capacity (TLC).



Identifying Lung Volumes

Tidal Volume (TV). The amount of gas inspired or expired with each breath.

Inspiratory Reserve Volume (IRV). Maximum amount of additional air that can be inspired from the end of a normal inspiration.

Expiratory Reserve Volume (ERV). The maximum volume of additional air that can be expired from the end of a normal expiration.

Residual Volume (RV). The volume of air remaining in the lung after a maximal expiration. This is the only lung volume which cannot be measured with a spirometer.

Lung capacities are subdivisions of total volume that include two or more of the 4 basic lung volumes.

Identifying Lung Capacities

Total Lung Capacity (TLC). The volume of air contained in the lungs at the end of a maximal inspiration. Called a capacity because it is the sum of the 4 basic lung volumes. TLC = RV+IRV+TV+ERV

Vital Capacity (VC). The maximum volume of air that can be forcefully expelled from the lungs following a maximal inspiration. Called a capacity because it is the sum of inspiratory reserve volume, tidal volume, and expiratory reserve volume. VC = IRV+TV+ERV=TLC-RV

Functional Residual Capacity (FRC). The volume of air remaining in the lung at the end of a normal expiration. Called a capacity because it equals residual volume plus expiratory reserve volume. FRC = RV+ERV

Inspiratory Capacity (IC). Maximum volume of air that can be inspired from end expiratory position. Called a capacity because it is the sum of tidal volume and inspiratory reserve volume. This capacity is of less clinical significance than the other three. IC = TV+IRV

Measuring Lung Volumes

Body Plethysmography

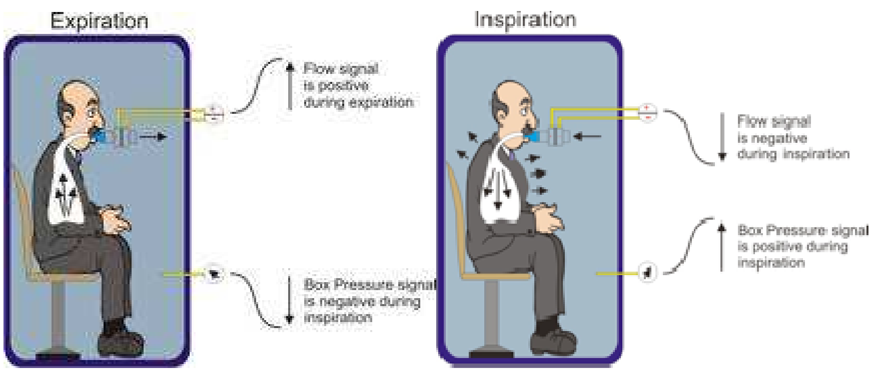
The penultimate way to measure lung volumes is body plethysmography. With this instrument, the volumes of the lung are evaluated by pressure change. Body plethysmography is the most accurate means available at this time to assess lung volumes because it is not limited by air trapping.

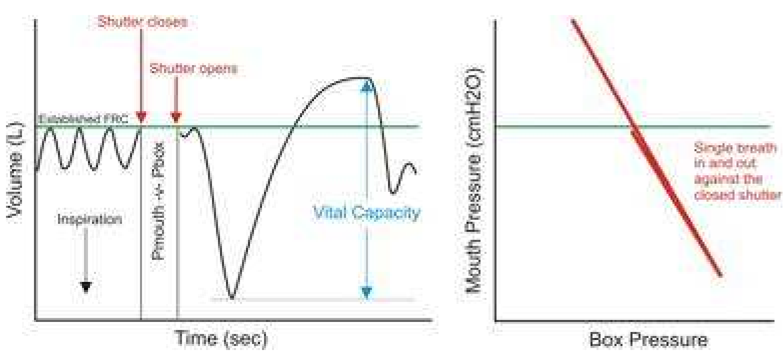
If you have a closed container where volume can be adjusted using a reciprocating pump (typically 30ml) then the pressure in the container increases in amount proportional to the fractional decrease in container volume (i.e. PV=k).

- Boyle's Law states that:
    - **V1 P1 T1 = V2 P2 T2**
        - For the plethysmograph, the temperature is kept constant so:
    - **P1 V1 = P2 V2**
        - Where:
          P1 and **V1** are initial pressure and volume.
          P2 and **V2** are final pressure and volume.
          Note: Both measurements are made at a constant temperature.

To calibrate the box pressure signal, a 30ml sinusoidal pump is used with the cabin door closed and the box sealed. The 30ml stroke of volume in and out of the sealed box causes a change in the box pressure signal. Thus the pressure change can be calibrated against a known volume.

In body plethysmography, the patient sits inside an airtight box, inhales or exhales to a particular volume (usually FRC), and then a shutter drops across their breathing valve. The subject makes respiratory efforts against the closed shutter causing their chest volume to expand and decompressing the air in their lungs. The increase in their chest volume slightly reduces the box volume and thus increases the pressure in the box. This method of measuring FRC actually measures all the conducting pathways including abdominal gas; the actual measurement made is VTG (Volume of Thoracic gas).





To compute the volume of air in the lungs, we first compute the change in volume of the chest. Using Boyle's Law (P1 V1 = P2 V2 at constant temperature), we set the initial pressure in the box times the initial volume of the box (both of which we know), equal to the pressure times volume of the box at the end of a chest expansion (of which we only know the pressure).

The volume of the box during respiratory effort is solved. The difference between this volume and the initial volume of the box is the change in volume of the box, which is the same as the change in the volume of the chest.

Helium Dilution

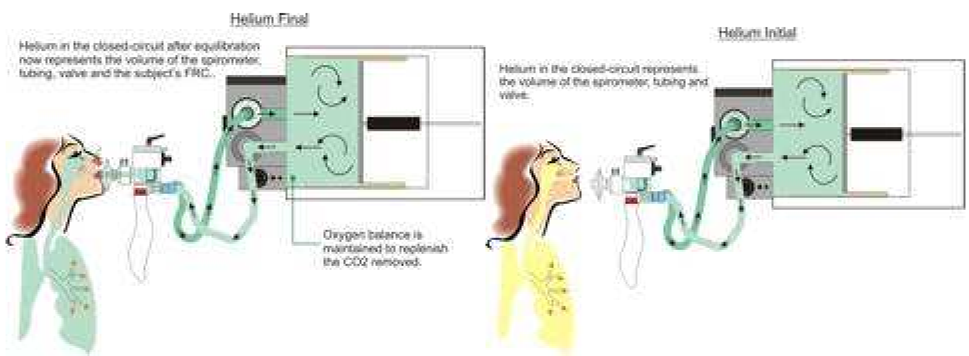
Helium dilution is a classic method used to measure the lung volume and capacities. The origins of the technique are reputed to date back to Sir Humphrey Davy's book, *"Researches Chemical and Philosophical"*, published in 1799, describes the measurement of his own lung volumes, including the first recorded measurement of the residual volume. He also measured his own rates of oxygen consumption and carbon dioxide production. He is famous for his investigations into nitrous oxide, but he also investigated the effects of breathing nitric oxide and carbon monoxide. He made these observations with a gasometer and analysis of his expired air, and his work anticipated the invention of blood gas analysis.

Why use helium?

Helium is an inert (lighter than air), colorless, odorless, tasteless gas and is not toxic. Furthermore, it cannot transfer across the avleolar-capillary membrane and is thus contained when in the lungs.

Closed circuit helium dilution studies have been a standard method of measuring the 'hidden' residual volume in the lung for many years.

The method employs the simple principle of gas dilution using helium, an insoluble inert gas that mixes easily in the lungs.



During helium dilution measurement of lung volumes, patients breathe from a known volume and concentration of helium gas for a period of typically 4 to 7 minutes. The oxygen concentration in the starting mixture is set at 30% to ensure patients with COPD can remain comfortable during the test. A carbon dioxide absorber is situated in line with expired breath to keep the closed-circuit CO_2 level below 0.5% and avoid discomfort and hyperventilation. Oxygen is added to the system to maintain the starting volume in the spirometer. A simple algorithm corrects the helium signal for changes in oxygen background.

Once connected to the closed-circuit, equilibration between the starting and final helium concentrations should occur within 7 minutes. A state of equilibrium is defined as helium concentration changes of less than 0.02% over a 30 second interval.

The functional residual capacity (FRC) is calculated from the helium concentrations as follows:

FRC = (% helium initial - % helium final) / % helium final x system volume

The dead space of the system (patient valve, filter and mouthpiece) is subtracted from this value.

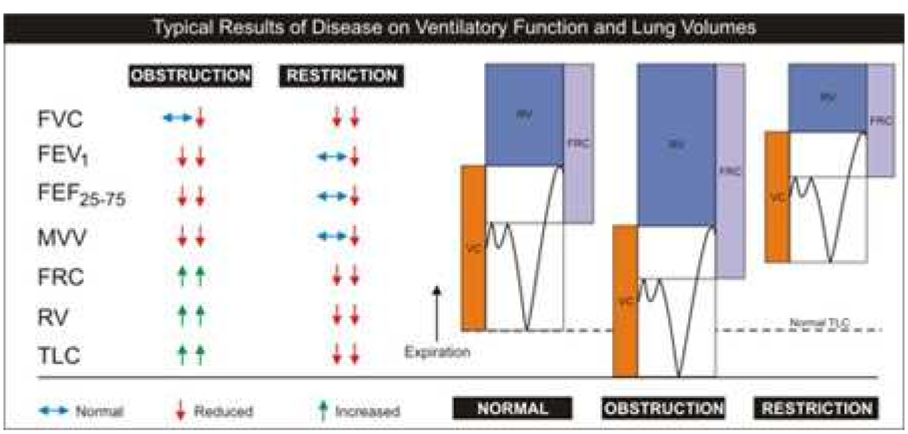
The FRC can be underestimated with the helium dilution technique in conditions such as bullous emphysema or severe airways obstruction. Trapped lung gas does not communicate with the inhaled helium mixture. Plethysmographic measurement of lung volumes is preferred in these cases.

The FRC can be overestimated or unmeasurable when leaks are present. Leaks may develop in the equipment valves or circuitry, or, more commonly, at the mouthpiece. A system leak is likely to be the cause if the graph of the delivered helium concentration does not flatten, ie, when equilibrium is not reached, within 7 minutes.

Nitrogen Dilution (Recovery)

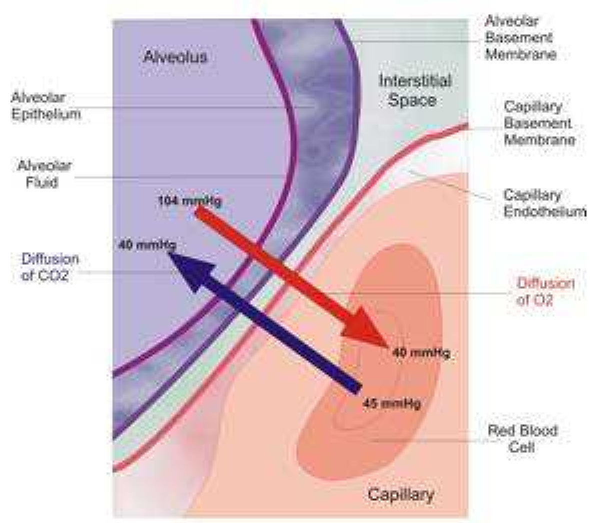
Nitrogen recovery is another gas dilution technique for measuring lung volumes. Only those instruments that can measure DLCO can offer N2 recovery ability. Since N2 is resident in the lung at all times, it has an infinite time to reach whatever communicating airways it can. During the performance of DLCO, the subject exhales to residual volume (all the way empty) and then breathes-in diffusion gas until completely full (TLC). The new N2 from the DLCO mixture rapidly mixes with the N2 that was in the residual volume and thus TLC can be directly measured. The technique has to assume the partial pressure of CO2 in the alveolar at the start of the test. For this reason, having a separate measure of PACO2 (alveolar CO2) from an end-tidal CO2 monitor can greatly improve accuracy on patients with COPD.

Chart Showing the Typical Results of Disease on Spirometry and Lung Volum es



Lung Diffusing Capacity

This test is used to evaluate how well oxygen moves into and out of the lungs. Certain diseases will lead to difficulties in getting oxygen from in the alveoli (air sac in the lung) into the blood where it is carried to the rest of the body.



In many ways, DLCO is a general measure of the complete ‘efficiency’ of the lungs because it is influenced by three key components: The surface area of the lung with contact to diffusing alveoli (VA - Alveolar Volume), the thickness of the alveolar-capillary membrane (Dm - Membrane Diffusion) and the volume of blood available in the capillary bed of the lung (Vc - Capillary Blood Volume).

- DLCO may be abnormal in conjunction with obstructive, restrictive, or normal spirometry.
- Increased DLCO is rarely important but may occur with polycythemia or lung hemorrhage.
- DLCO can help distinguish emphysema from chronic bronchitis.
- Asthma produces a normal and sometimes increased DLCO.
- A reduced DLCO with a reduced TLC is indicative of parenchymal disease (eg, interstitial fibrosis), which impairs the diffusion of oxygen from the alveoli to the capillaries.
- Normal DLCO with reduced TLC: The lung parenchyma is not damaged and the restriction is extrapulmonary.
- Decreased DLCO with normal spirometry and lung volumes: decreased oxygen-carrying capacity.
- Reduced DLCO infers interstitial disease suspected by history and physical examination. Obtain chest CT.
- Pulmonary vascular disease may present with decreased DLCO with normal spirometry and lung volumes. Occlusion of part of the pulmonary vascular bed reduces blood flow and decreases diffusion capability.

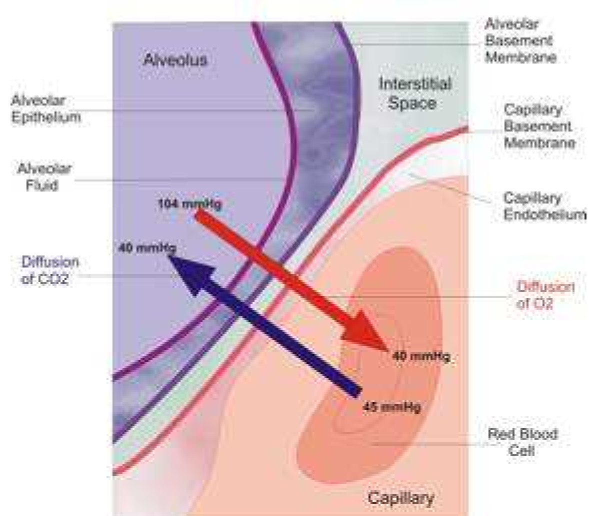
In this test we use a special gas mixture containing 0.300% CO, 10.0% Helium, 21,0% O2 and balance N2. The CO is used to trace the diffusion in place of O2 because it is a one-way transfer across the alveolar-capillary membrane for combination with Hb. The helium in the mixture is used to obtain a measure of the alveolar volume.
The challenge of Single Breath Diffusion testing is to obtain a representative sample of gas from an area of the lungs where diffusion is taking place. The patient first breathes all the way out to residual volume and is then connected to the test gas. They breathe all the way in to TLC and are then instructed to hold their breath for approximately 10 seconds. After having held your breath for ten seconds, the first amount of gas that leaves your lips when you breathe out, has been resident in the physiological dead-space (mouth, trachea and two main bronchi) and must therefore be discarded before collecting a valid gas sample.

At the conclusion of the test, the software automatically makes measures of the content of the inspiratory and expiratory bags.

- **Parameters:**
  - **DLCO** Single Breath Diffusing Capacity
  - **VA** Alveolar Volume
  - **DL/VA** Diffusion per unit area of Lung Volume

Lung Diffusing Capacity

This test is used to evaluate how well oxygen moves into and out of the lungs. Certain diseases will lead to difficulties in getting oxygen from in the alveoli (air sac in the lung) into the blood where it is carried to the rest of the body.



In many ways, DLCO is a general measure of the complete ‘efficiency’ of the lungs because it is influenced by three key components: The surface area of the lung with contact to diffusing alveoli (VA - Alveolar Volume), the thickness of the alveolar-capillary membrane (Dm - Membrane Diffusion) and the volume of blood available in the capillary bed of the lung (Vc - Capillary Blood Volume).

- DLCO may be abnormal in conjunction with obstructive, restrictive, or normal spirometry.
- Increased DLCO is rarely important but may occur with polycythemia or lung hemorrhage.
- DLCO can help distinguish emphysema from chronic bronchitis.
- Asthma produces a normal and sometimes increased DLCO.
- A reduced DLCO with a reduced TLC is indicative of parenchymal disease (eg, interstitial fibrosis), which impairs the diffusion of oxygen from the alveoli to the capillaries.
- Normal DLCO with reduced TLC: The lung parenchyma is not damaged and the restriction is extrapulmonary.
- Decreased DLCO with normal spirometry and lung volumes: decreased oxygen-carrying capacity.
- Reduced DLCO infers interstitial disease suspected by history and physical examination. Obtain chest CT.
- Pulmonary vascular disease may present with decreased DLCO with normal spirometry and lung volumes. Occlusion of part of the pulmonary vascular bed reduces blood flow and decreases diffusion capability.

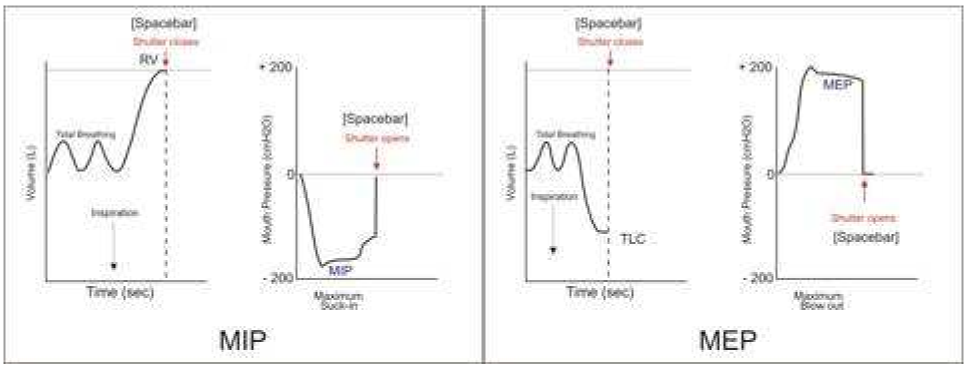
In this test we use a special gas mixture containing 0.300% CO, 10.0% Helium, 21,0% O2 and balance N2. The CO is used to trace the diffusion in place of O2 because it is a one-way transfer across the alveolar-capillary membrane for combination with Hb. The helium in the mixture is used to obtain a measure of the alveolar volume.
The challenge of Single Breath Diffusion testing is to obtain a representative sample of gas from an area of the lungs where diffusion is taking place. The patient first breathes all the way out to residual volume and is then connected to the test gas. They breathe all the way in to TLC and are then instructed to hold their breath for approximately 10 seconds. After having held your breath for ten seconds, the first amount of gas that leaves your lips when you breathe out, has been resident in the physiological dead-space (mouth, trachea and two main bronchi) and must therefore be discarded before collecting a valid gas sample.

At the conclusion of the test, the software automatically makes measures of the content of the inspiratory and expiratory bags.

- **Parameters:**
    - **DLCO** Single Breath Diffusing Capacity
    - **VA** Alveolar Volume
    - **DL/VA** Diffusion per unit area of Lung Volume

Respiratory Muscle Strength (MIP MEP)

There are diseases that can affect the muscles throughout the body. The muscles of breathing are the same as those in the leg or the arm. There are groups of muscles used to inhale (breath in) and exhale (breath out). When these muscles become weak, it can lead to problems with difficulty breathing. This test is designed to evaluate those muscles of breathing. The test is often called MIP/MEP - maximum inspiratory and expiratory pressure.

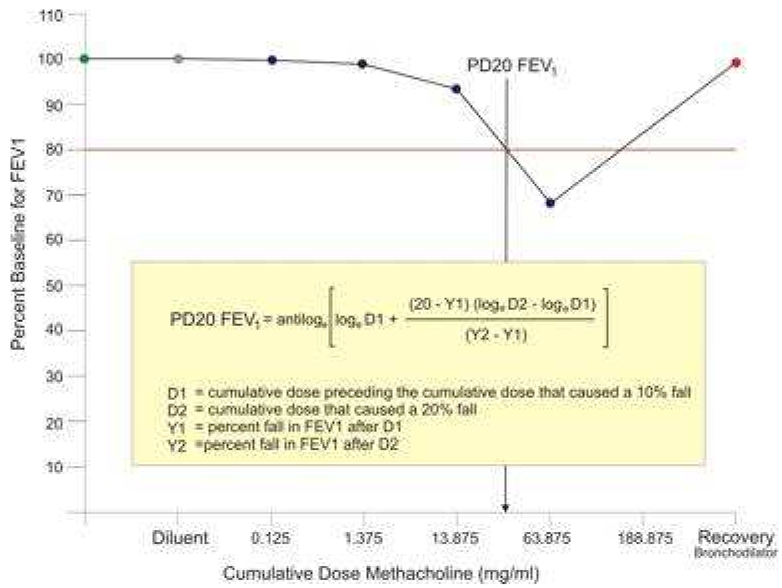


Bronchial Provocation (Challenge) Testing

When the physician assessing a patient is concerned that they might have asthma, first spirometry is performed. If no obstruction is identified further testing is sometimes required. A medication called methacholine is used to ‘provoke’ airway response.

When the airways of people with asthma are exposed to this medication, it will stimulate a response, which can be measured. If there is a positive response, asthma can be clearly identified and treated appropriately.

In most cases, methacholine challenge testing involves repeated FEV1 efforts at increasing levels of the drug. The sooner the patient reacts by a 20% reduction in their FEV1 compared to room air (normal) conditions the more likely their prevalence to asthma.



Challenge testing determines presence of airway hyper reactivity. After initial spirometry, patient inhales a specific concentration of methacholine chloride and spirometry is repeated. A reduction in FEV1 20% below the prior test indicates asthma.