4 Pulmonary Function Testing: Spirometry: Presence and Severity of Airflow Limitation/Obstruction

Key Points
1. Spirometry is used to detect airflow limitation which is a key component for the diagnosis of COPD.
2. Spirometry testing must be done correctly to obtain acceptable and repeatable results.
3. Airflow limitation is present when the ratio of the post-bronchodilator forced expiratory volume in one second divided by the forced vital capacity (FEV₁/FVC) is less than the lower limit of normal or < 0.70.

4.1 Introduction

COPD is characterized by airflow limitation that does not normalize after the use of a bronchodilator. Spirometry is the diagnostic test that is used to confirm the presence of airflow limitation. However, the clinical diagnosis of COPD requires more than the establishment of spirometry-determined airflow limitation. There should also be the presence of appropriate symptoms and known risk factors. As discussed in Chapter 3 on the recognition and diagnosis of COPD, this condition is more of a syndrome than a disease, with the diagnosis depending on the findings of appropriate symptoms in the right clinical context with airflow obstruction noted on spirometry testing. Once a screening questionnaire has identified an individual who may have COPD (by symptoms and history), spirometry is then performed. See Figure 4.1 for an example of a patient undergoing spirometry testing.

Spirometry is a test of respiratory function that measures the volume of air that an individual can inhale and exhale, usually in a forceful manner. After the individual fills his or her lungs to maximal capacity, he or she is asked to exhale forcefully while the exhaled volume is measured over time until the expiration is complete. When graphed, this volume–time relationship is known as a spirogram. The device used for the measurement is a spirometer. The important parameters determined by this test include:
- the total volume that is exhaled forcefully; the forced vital capacity (FVC);
- the volume of air that is exhaled in the first second of time; the forced expiratory volume in 1 second (FEV₁);
- the ratio between these two values: FEV₁/FVC.

Spirometry is useful in the evaluation of a patient who presents with respiratory symptoms (e.g., dyspnea, cough, sputum production, chest tightness, and wheezing).
Thus, the results of spirometry can be interpreted according to specific patterns of normality or abnormality, including airflow obstruction, possible lung restriction, or a mixed pattern of obstruction and possible restriction. If the spirometry test results are interpreted as abnormal, the individual may then be referred for more complete pulmonary function testing and further evaluation.

4.2 Reasons for Spirometry Testing

Reasons for performing spirometry in a clinical setting include:
- Evaluate dyspnea or shortness of breath in an individual
- Determine the presence and type and severity of pulmonary impairment or limitation
- Pre-operative assessment to determine the respiratory risk of a patient being considered for surgery

Figure 4.1: An individual performing spirometry with a technician coaching him.
- Detect if there are changes in lung function over time that may indicate development or worsening of a pulmonary disease
- Determine the benefits or worsening effects of treatment
- Identification of a patient with chronic obstructive pulmonary disease or COPD

It is this last reason that is the focus of this chapter and this primer.

### 4.3 Spirometry Screening for COPD

Although it has been previously suggested that spirometry should be performed in any individual over 45 years of age who is a smoker for the identification of patients with COPD (Ferguson, 2000), the U.S. Preventive Services Task Force in March of 2008 released a recommendation that spirometry was not indicated as a screening test for COPD unless the individual presented with respiratory symptoms including chronic cough, increased sputum production, wheezing or dyspnea (USPSTF, 2008). More recently, the US Preventive Services Task Force is re-examining its position for spirometry screening for COPD asking the question whether screening asymptomatic adults age 40 years and older for COPD could improve health-related quality of life or reduce morbidity or mortality (USPSTF, 2014). However, there may also be selected populations such as U.S. Veterans who have a high rate of smoking and both an increased prevalence of COPD as well as undiagnosed COPD (Murphy, 2013). It is in this population that efforts are being focused to use a specifically designed questionnaire (Sogbetrún, 2014) followed by spirometry to screen for airflow obstruction and COPD.

### 4.4 Limitations of Spirometry

Although spirometry can provide useful diagnostic and screening information, it has a few limitations. As a screening test, the results of spirometry can show normal results or restrictive or obstructive disease patterns, but the results cannot identify a specific disease. For example, a person’s spirogram may show a low FEV₁, but a physician may not be able to determine whether the cause is from asthma, emphysema, or some other obstructive or restrictive lung disease. Additional information, including health and exposures histories, physical examination, chest imaging, and other pulmonary function testing such as lung volumes and diffusing capacity may be needed to make a diagnosis.

Spirometry often can detect obstructive diseases in its early stages, but for some of the restrictive diseases, it may not be sensitive enough to show abnormalities before extensive, and in some cases, irreversible damage has been done. For example, presence of interstitial markings may be found on chest radiographs or CT scans of the chest while spirometry results are still within normal limits.
Three Phases of a Spirometry Test

The actual performance of a spirometry test is made up of three separate but critical phases:

1. The subject must take in as deep of breath as possible filling his or her lungs to total lung capacity
2. Then without hesitation, the subject must blast out or exhale the air forcefully
3. The subject should then continue to exhale until told to stop or unable to continue

See Figure 4.2 for an image showing the three phases of a spirometry test.

As will be discussed later, the performance of spirometry must meet certain criteria of acceptability and repeatability that depend on the ability of the subject to perform successfully each of these three phases of the test.
4.6 Displaying the Results of Spirometry Testing

When a spirometry test is performed, the technician coaches the subject or patient to take in a deep inspiration to completely fill their lungs and then without hesitation to exhale forcefully into the spirometer. The resulting exhaled volume of air and the flow rate of the exhaled air are measured and plotted on two different graphs (see Figure 4.3 and 4.4 for one form of the display of spirometry testing: volume of exhaled air against the time of exhalation).
Three spirometric measurements are particularly useful: **forced vital capacity (FVC)**, **forced expiratory volume at one second (FEV₁)**, and the **ratio of the FEV₁ to the FVC (FEV₁/FVC)**. Computerized spirometers frequently print out six or more measures of flow or volume. However, for most purposes, the FVC and FEV₁ suffice. The FVC is the total volume of air exhaled after a **Forced Expiratory Maneuver** (the act of exhaling as hard and fast as possible after maximal inspiration). The FEV₁ is the amount of air that a person breathes out during the first second of a forced expiratory maneuver.

Figure 4.5 is a different presentation of the data obtained with spirometry: the display of the flow rate of exhaled and inhaled air against the volume of air exhaled. This type of graphical representation (flow-volume curve) is quite useful in assessing the quality of spirometry testing especially for the first second of exhalation. The different colored lines refer to the baseline measurement of spirometry (red line) and repeat spirometry after the administration of a bronchodilator (blue line). Also, the...
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dots refer to the predicted values for flow rates for this individual. The volume-time graphs are also shown in this figure for pre- and post-bronchodilator spirometry. The FVC is the greatest point of the curve on the x-axis (in this example, it is 4.7 liters). However, the FEV₁ is not obvious since the time of exhalation is not shown. Instead, the spirometer has marked the location of the FEV₁ by a vertical line on the exhalation limb of the flow volume loop (in this example, the FEV₁ is 3.9 liters).

Spirometry test results can include many more parameters of exhaled flow including the peak expiratory flow rate (FEFmax) and mid-expiratory flow rates (FEF25–75%) as well as other instantaneous flow rates (FEF50%). However, for practical and clinical purposes, the three parameters mentioned below are the most important:
- Forced Vital Capacity (FVC) expressed in liters
- Forced Expiratory Volume in One Second (FEV₁) also expressed in liters
- The ratio of FEV₁/FVC expressed in percentage (%)

4.7 Acceptability and Repeatability Criteria of Spirometry Testing

Spirometry testing must be done in a high quality manner to obtain accurate information about the lung health of each patient. To ensure that the test results provide us with truly representative information, each forced maneuver must be examined for acceptability and each test session must be examined for repeatability. These criteria of acceptability and repeatability are described in detail in the American Thoracic Society/European Respiratory Society (ATS/ERS) recommended guidelines for spirometry testing (Miller, 2005). Spirogram results are used to detect possible conditions that affect the subject’s ability to exhale as fully and forcefully as possible. The results are compared either to the subject’s previous spirogram results if they are available or to established reference or predicted results that would be expected for a person with his/her characteristics (e.g., sex, age, height, etc.). If inaccurate results are obtained, the information from the comparisons will not be correct, creating the potential for not detecting serious lung diseases, or, diagnosing disease where none exists. Therefore, the goal of each testing session is to obtain acceptable maneuvers and a repeatable test session. That said, patients with lung disease may have a harder time producing acceptable and repeatable results. Acceptable tests are free from artifacts such as cough or glottis closure during the first second of exhalation, early termination (exhalation should be at least 6 seconds), variable effort, leak, or obstruction of the mouthpiece (Miller, 2005). There should be a quick start to the exhalation with the back extrapolated volume <5% of the FVC or 0.150 liters, whichever is greater. After three acceptable maneuvers the maximal two FEV₁’s and FVC’s should be within 150 ml of each other for the results to be repeatable (Miller, 2005). No more than 8 maneuvers should be attempted due to patient fatigue.
4.8 Measurements from Spirometry Testing

Once testing is completed, the spirometry test results for that individual (specifically the forced expiratory volume in one-second \( \text{FEV}_1 \), forced vital capacity (FVC) and the ratio of those two values \( \text{FEV}_1 / \text{FVC} \)) are compared to predicted values based on established reference equations e.g. the third National Health and Nutrition Examination Survey (NHANES III) reference equations for spirometry (Hankinson, 1999).

4.9 Patterns of Spirometry Impairment or Limitation

In addition to a normal pattern of spirometry test results, different impairments produce distinct spirometry patterns:
- Obstructive Defect Pattern or Airflow Limitation or Obstruction
- Restrictive Lung Defect Pattern
- Mixed Impairment with both Airflow Obstruction/Limitation and Lung Restriction.

4.9.1 Airflow Obstruction Pattern

In this pattern, the rate of airflow is reduced due to either narrowing of the airways in the lung (as in asthma or chronic bronchitis) or loss of elastic recoil (as in emphysema) reducing the rate of exhaled airflow. See Figure 4.6 and 4.7 for volume time displays of the airflow obstruction pattern.

With airflow obstruction, there is a reduction in the amount of air that is exhaled in the first second \( \text{FEV}_1 \) as well a reduction in the ratio of \( \text{FEV}_1 \) to FVC. In fact, it is the reduced ratio of \( \text{FEV}_1 \) to FVC or \( \text{FEV}_1 / \text{FVC} \% \) that is the hallmark of airflow obstruction. In this example, the normal spirometry results show a \( \text{FEV}_1 \) of 3.0 liters and a FVC of 4.0 liters; therefore, the ratio of \( \text{FEV}_1 / \text{FVC} \) is 3.0/4.0 or 75%. For the spirometry showing airflow obstruction or limitation, the \( \text{FEV}_1 \) is 1.0 liters, the FVC is 3.7 liters, and the ratio of \( \text{FEV}_1 / \text{FVC} \) is 1.0/3.7 or 27%.

See Figure 4.8 for an example of moderately severe airflow obstruction with a flow-volume display. At baseline, the FVC is 2.8 liters, the \( \text{FEV}_1 \) (by the vertical mark) is 1.3 liters, and the ratio of \( \text{FEV}_1 / \text{FVC} \) is 1.3/2.8 or 46%. After the bronchodilator, the FVC is now 3.7 liters, the \( \text{FEV}_1 \) is 1.9 liters and the \( \text{FEV}_1 / \text{FVC} \) is 1.9/3.7 or 51%.

Figure 4.9 is an example of severe airflow obstruction with a flow-volume display. Examples of lung diseases with airflow obstruction are COPD including chronic bronchitis and emphysema, asthma, bronchiectasis, and bronchiolitis obliterans.
Figure 4.6: Volume-time graph of Airflow Obstruction. In this case, as compared to a normal pattern of exhaled volume of air, there is a decreased volume of exhaled air in the first second of exhalation.

Figure 4.7: Volume-time graph of airflow obstruction showing measurements of FEV₁ and FVC and the ratio of FEV₁ to FVC (FEV₁/FVC)
4.9.2 Restrictive Lung Defect Pattern

In the case of a restrictive lung defect pattern, the total amount of exhaled air is reduced. This means the Vital Capacity or FVC is reduced. See Figure 4.10 and 4.11 as examples of volume-time displays of a restrictive lung defect.

In a restrictive lung defect, the rate of emptying of the air from the lung may not be reduced so the relationship between FEV₁ and FVC is normal. That said, because the FVC is reduced, the FEV₁ will be reduced proportionally with the FEV₁/FVC ratio being maintained and not reduced or, even on occasions, increased. In this particular case, the FVC is reduced as is the FEV₁, but the ratio of FEV₁/FVC is maintained or even increased compared to normal. For a restrictive lung defect, the hallmark is the reduced FVC. In this example, the normal spirometry results show an FEV₁ of 3.0 liters and FVC of 4.0 liters for a ratio of FEV₁/FVC of 3.0/4.0 or 75%. For the spirometry showing restriction, the FEV₁ is 1.8 liters, the FVC is 2.2 liters and the ratio of FEV₁/FVC is 1.8/2.2 or 82%.

See Figure 4.12 and 4.13 as examples of flow-volume displays of restrictive lung disease.

Since spirometry cannot measure the residual volume and, in turn, cannot determine the total lung capacity, spirometry can only suggest the presence of an actual restrictive lung defect. Further testing with lung volume measurements would be needed to confirm the presence of restriction.

Examples of lung diseases that can have a restrictive lung defect include interstitial fibrosis, hypersensitivity pneumonitis, pleural disease, chest wall deformities, pulmonary edema, and obesity.

4.9.3 Mixed Impairment with both Airflow Obstruction and Lung Restriction

Mixed impairment may be seen with combined lung diseases: a patient with a long smoking history who has COPD as well as the development of severe obesity leading to a restrictive lung defect. See Figure 4.14, 4.15 and 4.16 as examples of a volume time tracing and flow-volume displays for a mixed impairment result.

4.10 Interpretation of Spirometry Results

4.10.1 Reference Equations

There have been many studies published in the medical literature which have determined spirometry reference values from groups of relatively healthy persons. At this time, the American Thoracic Society (ATS) recommends using the reference values based on the third National Health and Nutrition Examination Survey (NHANES III) (Hankinson, 1999).
Figure 4.8: Flow-volume loop of Moderate Severity Airflow Obstruction. As can be seen in this graphical representation, the flow rate of air during exhalation is reduced throughout exhalation. This gives increased curvature or a greater concave shape to the expiratory limb of the flow volume loop which is another hallmark of airflow obstruction. Again, the different colored lines refer to pre-bronchodilator or baseline spirometry testing (red line) and post-bronchodilator testing (blue line).

Figure 4.9: Flow-volume loop of Severe Airflow Obstruction In this example, there is more severe airflow obstruction which can be seen by even more severely decreased expiratory flow rates. At baseline, the FVC is 2.7 liters and the FEV₁ is 0.4 liters for a ratio for FEV₁/FVC of 15%. After the bronchodilator, the FVC is 3.1 liters and the FEV₁ is 0.6 liters for a ratio for FEV₁/FVC of 19%.
Figure 4.10: Volume-time graph of Restrictive Lung Defect Pattern. In the case of a restrictive lung defect pattern, the total amount of air exhaled is reduced. This means the Vital Capacity or FVC is reduced.

Figure 4.11: Volume-time graph of Restrictive Lung Defect showing measurements of FEV₁ and FVC and the ratio of FEV₁ to FVC (FEV₁/FVC).
Figure 4.12: Flow-volume loop of a Restrictive Lung Defect. In a restrictive lung defect, the flow rates are maintained but the vital capacity (FVC) is reduced. This gives the appearance of a more vertical or upright flow-volume loop. In this case at baseline, the FVC is 3.2 liters and the FEV₁ is 2.9 liters for a ratio of FEV₁/FVC of 91%. There is really not much change after the use of a bronchodilator.

Figure 4.13: Another example of a Flow-volume loop for a Restrictive Lung Defect. Again note the more vertical appearance of the flow-volume loop in contrast to the horizontal appearance of the flow-volume loop for the patient with severe airflow obstruction. At baseline, the FVC is 3.2 liters and the FEV₁ is 2.7 liters for a ratio of FEV₁/FVC of 84%.
4.10.2 Racial Differences in Reference Equations

The NHANES III study provides a separate set of spirometry reference equations for men and women of African-American, Caucasian, and Mexican-American ethnic groups. The NHANES III study did not provide spirometry reference equations for Asian-Americans, American Indians, East Indians, or other ethnic groups. Other investigations suggest that spirometry results are not substantially different for American
Indians when compared to Caucasians living in the United States; therefore, NIOSH recommends that when testing American Indian patients, the reference equations for Caucasians be used. For Asian-Americans, until separate reference equations are published and accepted for Asian-American and East Indian ethnic groups, the NHANES III reference equations for Caucasians should be used, but a correction factor of 0.88 should then be applied to the predicted values for FVC and FEV₁ (Redlich, 2014).

4.10.3 The Lower Limit of the Normal (LLN) Range

The predicted value calculated from spirometry reference equations is the average or mean value observed from many healthy persons of the same age, gender, height, and race as the patient being tested. The predicted value is actually in the middle of a rather wide, bell-shaped distribution (range) of normal values. For instance, some healthy persons may have FVC values as much as 20% lower than the predicted value. The lower limit of the normal range (LLN) is the threshold below which a value is considered abnormal - usually the value is set so that 95% of a “normal” population will have values above the LLN value and, correspondingly, 5% of a “normal” population will have values below the LLN. The LLN is about 80% of the predicted value for FEV₁ and for FVC, but about 90% of the predicted value for the FEV₁/FVC ratio, and about 60% of the predicted value for the FEF25–75%. However, these are only rough “rules of thumb” and the exact LLN should be determined using the reference equations.
4.10.4 What is Considered to Be Abnormal?

Abnormalities detected by spirometry may show one of three patterns: obstructive, restrictive, or mixed impairment (both obstructive and restrictive). Patients with obstructive lung diseases, such as emphysema or chronic asthma, often have an abnormally low FEV₁/FVC and a low FEV₁ (below the LLN). Patients with fibrotic lung diseases, such as asbestosis, often have an abnormally low FVC, but their FEV₁/FVC will generally be above the LLN. Persons exposed to certain dusts, such as silica or coal mine dust, can develop either pattern of abnormality, or a mixed pattern with reductions of both the FEV₁/FVC ratio and the FVC below the LLN. Occasionally, spirometry results from a patient without any apparent health problems are found to be slightly below the LLN. In contrast, it is not unusual to have high FVC or high FEV₁ spirometry values. Young adults who were competitive athletes in high school, trade school, or college (while their lungs were still growing) may have a percent predicted FVC above 120%.

4.10.5 Determine Predicted Values and % of Predicted Values

Spirometry reference or predicted values, percent predicted values, and the LLN’s for an individual can be reported from the automated spirometry system that has already been programmed with the appropriate reference equations. The percent of predicted values refers to the actual measured value of the spirometric parameter (e.g., FEV₁ or FVC) divided by the predicted or reference value for that individual times 100 for %, or:

\[ \%\text{Pred FEV}_1 = 100.0 \times \frac{\text{Observed FEV}_1}{\text{Predicted FEV}_1} \]

4.10.6 Interpretation of Spirometry Test Results for Impairment Patterns

As mentioned above, lower limits of normal (LLN) for the spirometric parameters are used to determine whether the results are normal or abnormal. The primary impairment patterns of airflow obstruction, a restrictive lung defect and mixed impairment are then determined by interpretation using these LLNs.

4.10.7 Airflow Obstruction

The criterion for the interpretation of the presence of airflow obstruction is the finding of a reduced FEV₁/FVC or the numerical value of FEV₁/FVC below the LLN for that
value. Some providers may decide to use the guidelines from the Global initiative for Chronic Obstructive Lung Disease: GOLD criteria for airflow obstruction (GOLD, 2013), when interpreting the results of spirometry. Those guidelines define an absolute cutoff for FEV1/FVC of 70% to determine the presence of airflow obstruction. The American Thoracic Society and European Respiratory Society recommend using the LLN from the reference equations chosen for the interpretation of spirometry test results (Pelligrino, 2005), (see “Controversy for Determination of Airflow Limitation/Obstruction” below).

The primary determinant of airflow obstruction is the FEV1/FVC ratio measured by spirometry: If FEV1/FVC < LLN, then airflow obstruction is present.

Once airflow limitation is determined to be present, the severity of limitation is then assessed based upon the FEV1 % of predicted value. Using the ATS/ERS guidelines for Interpretative Strategies for Lung Function Tests (Pelligrino, 2005), the following severity categories are used:

- **Mild obstruction**: FEV1 % predicted > 70% (which means the actual value measured is greater than 70% of the predicted value which in turn is based on the patient’s age, height and gender with correction for race as appropriate).
- **Moderate obstruction**: FEV1 % predicted <69% but > 60%
- **Moderately severe obstruction**: FEV1 % predicted <59% but > 50%
- **Severe obstruction**: FEV1 % predicted <49% but > 35%
- **Very severe obstruction**: FEV1 % predicted <34%

There may be patients whose results from spirometry testing or from complete pulmonary function testing (if available) may be equivocal for the presence of airflow limitation or COPD. As discussed in Chapter 3 on the Recognition and Diagnosis of COPD, just as the syndrome of COPD may range from no evidence of airways disease to severe COPD, the presence of airflow obstruction is also a continuum from no airflow obstruction to very severe airflow obstruction. In the case of possible borderline airflow obstruction when the FEV1/FVC is above the LLN, the use of reduced mid-expiratory flow rates adjusted for the FVC (the mid-expiratory flow ratio or MEFR) may be helpful (see Chapter 3).

### 4.10.7.1 Possible Restrictive Lung Defect

Because spirometry cannot measure residual volume (RV) and in turn total lung capacity (TLC), the test cannot determine the presence of an actual restrictive lung defect where the total lung capacity is reduced below its LLN. Instead if the FVC is reduced below its LLN, then the presence of a restrictive lung defect can be suggested. However, it should be stated that further testing including the use of lung volumes will be needed to confirm the presence of an actual restrictive lung defect.
If only spirometry results are available, then the presence of restriction would be suggested if the FVC is < LLN (especially if the FEV₁/FVC ratio is > LLN); however the comment should be made that lung volumes would be recommended for confirmation of the presence of a restrictive lung defect.

### 4.10.7.2 Mixed Impairment Pattern

It is possible that there might be both the presence of airflow obstruction and the presence of a possible restrictive lung defect. In that case, a mixed impairment pattern may be interpreted.

- **Mixed impairment will be interpreted if there is both the presence of airflow obstruction and the suggestion of a restrictive lung defect.**

### 4.10.7.3 Controversy for Determination of Airflow Limitation/Obstruction

As mentioned previously, the determination of the presence of airflow limitation or obstruction is in most cases the finding of a reduced FEV₁/FVC ratio. The controversy has been deciding below what value the FEV₁/FVC is considered to be reduced. The definition of airflow limitation or airflow obstruction has been a point of discussion based upon different statements from professional groups. Clinical guidelines for COPD disease management include the Global Initiative for Chronic Obstructive Lung Disease (GOLD, 2013), the VA/DoD Clinical Practice Guideline for Management of Outpatient Chronic Obstructive Pulmonary Disease (VA/DoD, 2007), and the American Thoracic Society/European Respiratory Society Standards for the Diagnosis and Management of Patients with COPD (ATS, 2004). These three guidance documents have recommended being more inclusive for identifying individuals who may have COPD and have proposed that the presence of airflow limitation exists when the post-bronchodilator FEV₁/FVC ratio is < 0.70. These guidelines acknowledge that this approach may be overly sensitive and include older individuals who are normal but who have an FEV₁/FVC ratio that is < 0.70. Other guidance documents are based on a statistical approach for the interpretation of airflow limitation using reference equations which in turn are based on population studies. The ATS/ERS document on Interpretative Strategies for Lung Function Tests states that the presence of an obstructive ventilatory defect exists when the FEV₁/FVC ratio is below the 5th percentile of its predicted value, a value referred to as the lower limit of normal or LLN for that ratio based on the chosen reference values (Pelligrino, 2005). The most recent revised GOLD guidance (GOLD, 2013) acknowledges that the LLN values are based on a normal distribution and that the use of a fixed ratio of 0.70 will result in more frequent diagnosis of COPD in the elderly.

These different thresholds for the definition of airflow limitation or obstruction, a fixed cutoff of 70% for the ratio of FEV₁/FVC or the LLN for this ratio, can yield very different diagnoses as is illustrated in Figure 4.17. As we age, the normal values
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for FEV\textsubscript{i}/FVC decrease and, in turn, the values for the LLN for the ratio of FEV\textsubscript{i}/FVC also decrease. The regression line for the decline in the LLN for the FEV\textsubscript{i}/FVC ratio with increasing age based upon the NHANES III reference equation is shown in this figure. As a result, younger individuals with an FEV\textsubscript{i}/FVC above 70% but below the LLN would be classified as no airflow obstruction by use of a 70% cutoff but would be interpreted as airflow obstruction by use of the LLN (false negatives). On the other hand, older individuals with FEV\textsubscript{i}/FVC ratios below 70% but above the LLN would be classified as having airflow obstruction by the use of a 70% cutoff but would have no airflow obstruction by use of the LLN (false positives).

4.10.7.4 Bronchodilator Response

There are times when clinicians want to assess a patient’s spirometric response to the one-time use of a bronchodilator. In those instances, the % change and absolute change in volume of FEV\textsubscript{i} and FVC is determined comparing the post-bronchodilator spirometry results to the baseline or pre-bronchodilator results.

- A significant response to the one-time use of a bronchodilator is a 12% increase in FEV\textsubscript{i} or in FVC with at least a 200 ml increase in that measurement.

There needs to be both the 12% increase as well as the 200 ml change in absolute volume for a significant bronchodilator response to be interpreted. This definition of a significant bronchodilator response has been recommended by ATS/ERS in their 2005 statement of the interpretation of lung function testing (Pelligrino, 2005). As is also stated in this report, there may be other definitions of a significant bronchodilator response.
tor response. As an example, the topic of bronchodilator response was discussed in a recent point and counterpoint series of articles (Pelligrino, 2014; Hansen, 2014). The counterpoint argument to using a 12% and 200 ml increase in FEV1, and FVC is that depending on the quality and precision of the spirometry data, much lower values of an increase may be statistically significant.

Both the ATS/ERS and GOLD spirometry guidelines recommend the use of post-bronchodilator FEV1, FVC, and FEV1/FVC to determine the presence of airflow obstruction. Spirometry after bronchodilators is believed to reduce variability in the measurement of FEV1 and FVC and improve testing repeatability (GOLD, 2014). In addition, post-bronchodilator measurements should provide maximal flow rates and, therefore, represent an individual’s “best” or greatest lung function. Even among individuals with normal lung function, the FEV1, FVC, and FEV1/FVC generally increase slightly after administration of a short acting beta-agonist and this effect diminishes with increasing age (Johannessen, 2006).

### 4.11 Summary Points

1. The identification of a patient with COPD has required the demonstration of airflow obstruction or airflow limitation as determined by spirometry testing.
2. If spirometry is performed, the testing must be done according to criteria of acceptability and repeatability as recommended by the American Thoracic Society and the European Respiratory Society.
3. The interpretation of spirometry test results involves the comparison of the actual measured values with predicted or reference values with normal vs abnormal results determined by the use of lower limits of normal (LLN) for the measured parameter.
4. Spirometry test results can be interpreted as different patterns: normal, airflow obstruction, possible restrictive lung defect or a mixed impairment pattern.
5. Airflow obstruction is present when the FEV1/FVC ratio is below the LLN or a value of 0.70 for that parameter. Borderline airflow obstruction may be present when there is a reduction in the mid-expiratory flow ratio.

### References


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