# SYSTEMATIC APPROACH TO SPIROMETRY:

## A PRACTICAL GUIDE FOR EVALUATING LUNG FUNCTION IN PRACTICE

Use this page to quickly navigate to key sections of this resource. You can return to this page by clicking the home icon that appears on the bottom of every page.

### SPIROMETRY



### UNDERSTANDING PULMONARY FUNCTION TESTS



### FORCED EXPIRATORY VOLUME MANEUVER TIPS



PRECISION

PRECISION

# SPIROMETRY

## IMPORTANT TOOL

**Pulmonary function testing, using office-based spirometry in primary and subspecialty care, is an important tool to document expiratory airflow limitation in asthma patients.[1]**

Expiratory airflow varies to a greater extent, over time and in magnitude, in the asthma population than in a healthy population. In the same person with asthma, expiratory airflow may be completely normal or severely reduced over the course of one day, from day to day, from visit to visit, or seasonally. Greater variability occurs in patients with poorly controlled asthma than in patients with well-controlled asthma.[1]

Spirometry, when used along with a patient's history, physical examination, and ancillary testing, can help to differentiate among the potential causes of a patient's breathing abnormality,[2] and help health care providers initiate more appropriate treatment.[3]

## OFFICE-BASED TESTING

Spirometry is an inexpensive and user-friendly modality to measure lung function.[4] Primary care physicians or other health care professionals, including allergists and pulmonologists, are in an ideal position to perform spirometry during an office visit and apply the results to everyday clinical decision-making.[3]

**When a patient's spirometry results are abnormal, it is advisable to refer that patient to an asthma clinic or a specialist for evaluation.[3]**

## INDICATIONS

Spirometry is an accurate and reproducible test used to[2,3]:

- **Evaluate signs and symptoms of lung disease**
- **Assess progression of lung disease**
- **Monitor effectiveness of therapy**
- **Evaluate preoperative patients**
- **Screen at-risk smokers and workers with occupational exposures**
- **Monitor potentially toxic effects of certain drugs or chemicals**

# UNDERSTANDING PULMONARY FUNCTION TESTS

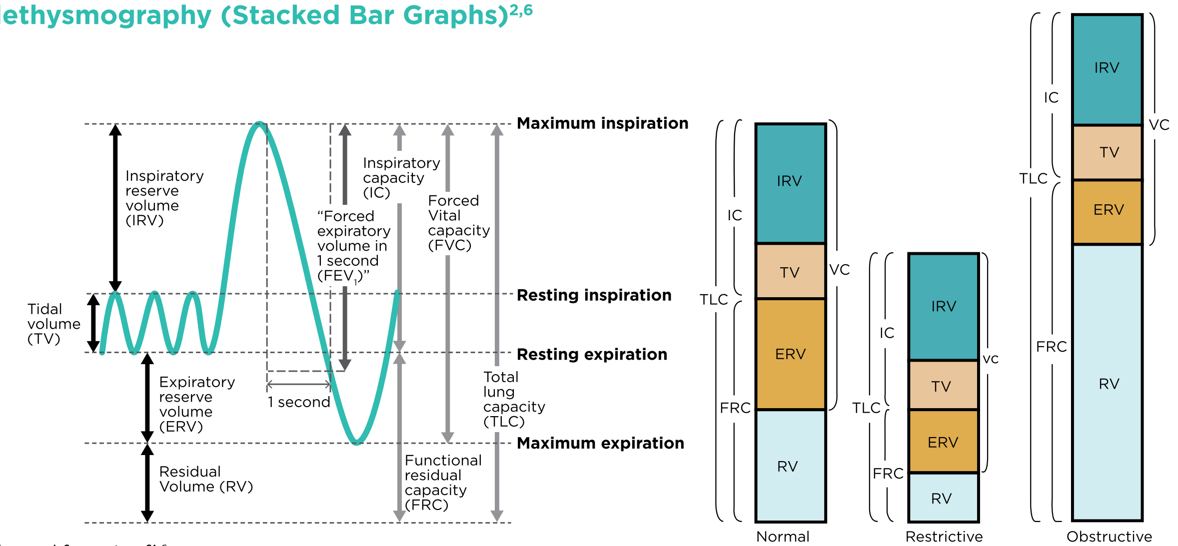
## LUNG VOLUME COMPONENTS

**Lung volumes are divided into several components: inspiratory reserve volume (IRV), tidal volume (TV), expiratory reserve volume (ERV), residual volume (RV), functional residual capacity (FRC), and total lung capacity (TLC).[2] The dynamic lung volumes measured by spirometry are shown in the left panel of the figure and static lung volumes obtained by body plethysmography are represented in the right panel.**

Lung volume measurements provide valuable data on lung function abnormalities. The rate of change in certain lung volumes can be measured by spirometry during a forced expiratory volume maneuver.[5] By interpreting spirometry test results in conjunction with a patient's history, physical exam, or other studies, patterns of lung function abnormalities, including obstruction, restriction, or mixed, can be identified.[2]

Before the forced expiratory volume maneuver, the patient "breathes normally." This is represented as tidal volume (TV) in the figure. At the start of the maneuver, the patient takes a full inhalation ("breathe in as deeply as you can") to total lung capacity (TLC) followed by a rapid, forced, maximal exhalation ("breathe out as hard and as long as you can") to the residual volume (RV).[2] To obtain a useful measure, expiration is continued for at least 6 seconds or until a plateau in exhaled volume is reached.[5] The total amount of air exhaled during this maneuver is the forced vital capacity (FVC).[4]

### Lung Volumes Measured by Spirometry (Volume-Time Spirogram) vs Body Plethysmography (Stacked Bar Graphs)[2,6]




Adapted from Lutfi.[6]

Definitions[2]: ERV—maximum volume of air that can be exhaled from the end-expiratory tidal position; IRV—maximum volume of air than can be inhaled from the end-inspiratory tidal position; $FEV_1$—volume of air that can be forcibly exhaled from a TLC in the first second; $FEV_1$/FVC ratio—identifies whether the pattern is obstructive, normal, or restrictive; FRC—volume of air in the lungs following a tidal volume exhalation (ERV + RV); FVC—total volume of air that can be forcibly exhaled from TLC to RV; IC—maximum volume of air that can be inhaled from tidal volume end-expiratory level (IRV + TV); RV—volume of air that remains in the lungs after maximal exhalation; TLC—total volume of air in the lungs at full inhalation (IC + FRC) or (IRV + TV + ERV + RV); TV—volume of air that is inhaled or exhaled when a person is breathing at rest; VC—vital capacity; the maximum volume of air that can be exhaled starting from maximum inhalation.

# TOTAL LUNG CAPACITY AND STATIC LUNG VOLUME MEASUREMENT

After a patient exhales maximally in the forced expiratory volume maneuver, some air remains in the lungs. This is referred to as the residual volume and it cannot be measured by spirometry. A method that can supplement the lung volume information obtained from spirometry is called body plethysmography. This method assesses FRC and airway resistance, from which RV, and then TLC, can be determined.[7]

A patient taking this test sits in an airtight box and inhales from FRC against a closed mouthpiece.[6] Testing is based on Boyle's law, so the change of volume in the airtight test box equals the change of volume in the patient's lungs.[8]

## FVC, $FEV_1$, AND $FEV_1$/FVC RATIO

Three important parameters that are routinely reported following a forced expiratory volume maneuver in spirometry testing are FVC, forced expiratory volume in 1 second ($FEV_1$), and $FEV_1$/FVC ratio.

1. FVC is the total amount of air that can be exhaled following a maximal inhalation Reduced FVC may be associated with lung function abnormalities.
2. $FEV_1$ is the amount of air exhaled during the first second of the forced expiratory volume maneuver. $FEV_1$ tends to be lower in diseases that obstruct the airways, including asthma.
3. $FEV_1$/FVC ratio is used to determine the pattern of lung function defect. A decreased $FEV_1$/FVC ratio identifies a patient with airway obstruction.

### Comparison of Obstructive and Restrictive Lung Impairment Patterns[2]

| | Obstruction | Restriction |
|---|---|---|
| $FEV_1$/FVC | Decreased | Normal |
| $FEV_1$ | Decreased | Decreased or normal |
| FVC | Decreased or normal | Decreased |
| TLC | Normal or increased | Decreased |

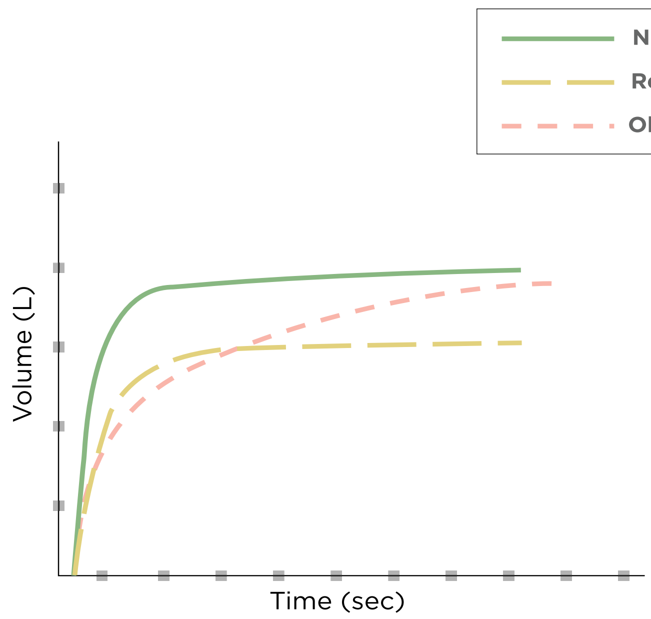
# VOLUME-TIME CURVE AND FLOW-VOLUME LOOP

The forced expiratory volume maneuver is graphed to allow for easy visualization of the lung volumes and rapid rise and plateau in airflow over time. The airflow rate should be at its highest near the start of the exhalation and then decline through the end of the exhalation. This is shown in the volume-time curve, which displays airflow volume (L) over time (sec).[2]

Similarly, when the forced expiratory volume maneuver begins, airflow rates are highest near TLC and then decline until RV is reached at the end of the maneuver. This is shown in the flow-volume loop, which displays maximal inspiratory and expiratory airflow (L/sec) related to lung volume (L) from RV to TLC during inspiration and then back to RV during expiration.[2] The flow-volume loop informs on whether airflow is appropriate for a particular lung volume.[8]

## Obstructive, Normal, and Restrictive Patterns on Spirograms

**Volume-Time Curve**




Adapted from: Respiratory. Health Spirometry Procedures Manual NHANES.[5]

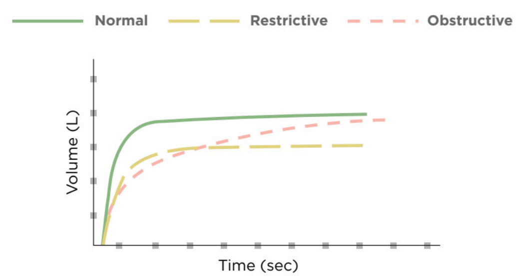
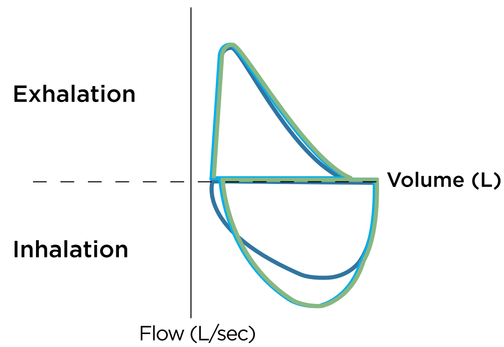
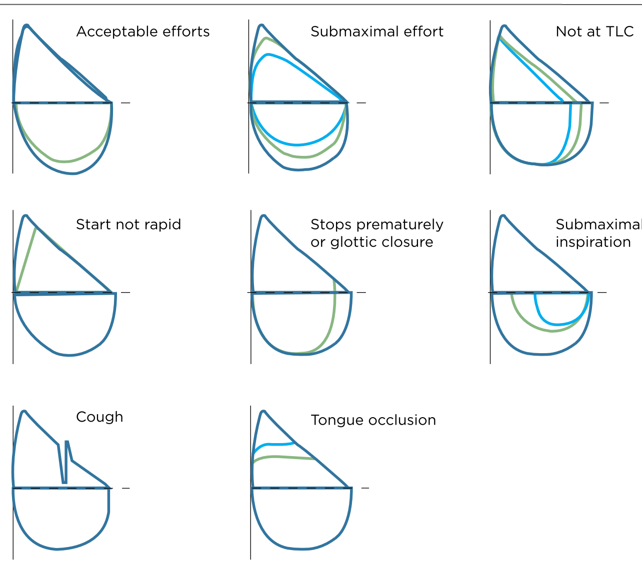
**Flow-Volume Loop**


Adapted from: Al-Ashkar.[2]

# SPIROGRAM ACCEPTABILITY AND REPRODUCIBILITY

To provide useful results, spirograms must meet certain criteria for acceptability, reproducibility, and absence of artifacts. Spirometry testing is repeated at least 3 times to obtain a minimum of 3 acceptable forced expiratory volume maneuvers.[9]

## Acceptable and Reproducible Spirograms

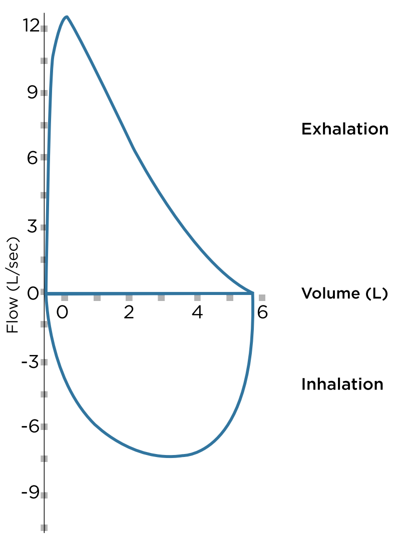
| Evaluate | Criteria | Example |
|---|---|---|
| Acceptability | Volume-time curve should have a rapid start, must plateau, and have duration of at least 6 seconds for adults[10]; (criteria for children may be different) |   Adapted from: Respiratory Health Spirometry Procedures Manual NHANES.[5] |
| Reproducibility | $FEV_1$ and FVC measurements from the 2 best efforts of at least 3 trials must be consistent, repeatable, and within 0.2 L of each other[10] |   Adapted from: Johnson.[10] |
| Absence of Artifacts | Flow-volume loops must be free from artifacts, submaximal effort, cough, slow start, early termination, glottis closure, submaximal inspiration, or tongue obstruction[9] |   Adapted from: Johns.[11] |

## UPPER AIRWAY OBSTRUCTION EVALUATION

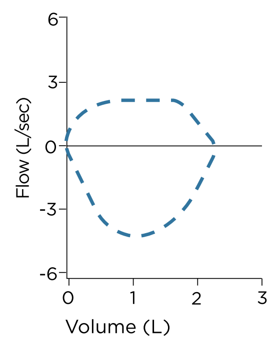
Flow-volume loops from forced inspiration and expiration are used to evaluate for upper airway obstruction. It is important to look at the shape of the entire flow-volume loop to understand upper airway obstruction.

The expiratory portion of the curve depicts the intrathoracic airways (eg, intrathoracic trachea, main bronchi, and central and peripheral airways), while the inspiratory curve depicts extrathoracic airways (eg, pharynx, larynx, and extrathoracic portion of the trachea).[12] A flattened inspiratory curve may be seen in some types of upper airway obstruction.[15]

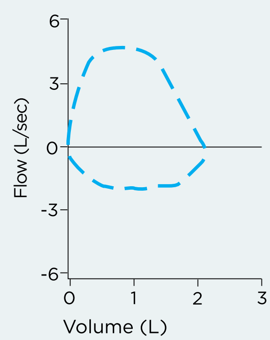
### Patterns of Obstruction With Associated Potential Diseases

<table>
<tr><th>Normal Flow-Volume Loop[4]</th><th colspan="3">Examples of Obstructive Pulmonary Defects[12]</th></tr>
<tr>
<td>
</td>
<td>

Fixed upper airway obstruction[15]

- Tracheal stenosis
- Goiter</td>
<td>

Variable intrathoracic upper airway obstruction[15]

- Tracheomalacia
- Bronchogenic cysts
- Malignant tracheal lesions</td>
<td>

Variable extrathoracic upper airway obstruction[15]

- Laryngomalacia
- Structural and functional vocal cord abnormalities
- Tracheomalacia</td>
</tr>
</table>

Adapted from: Barreiro[4]; Pellegrino.[12]

## SPIROMETRY TEST INTERPRETATION

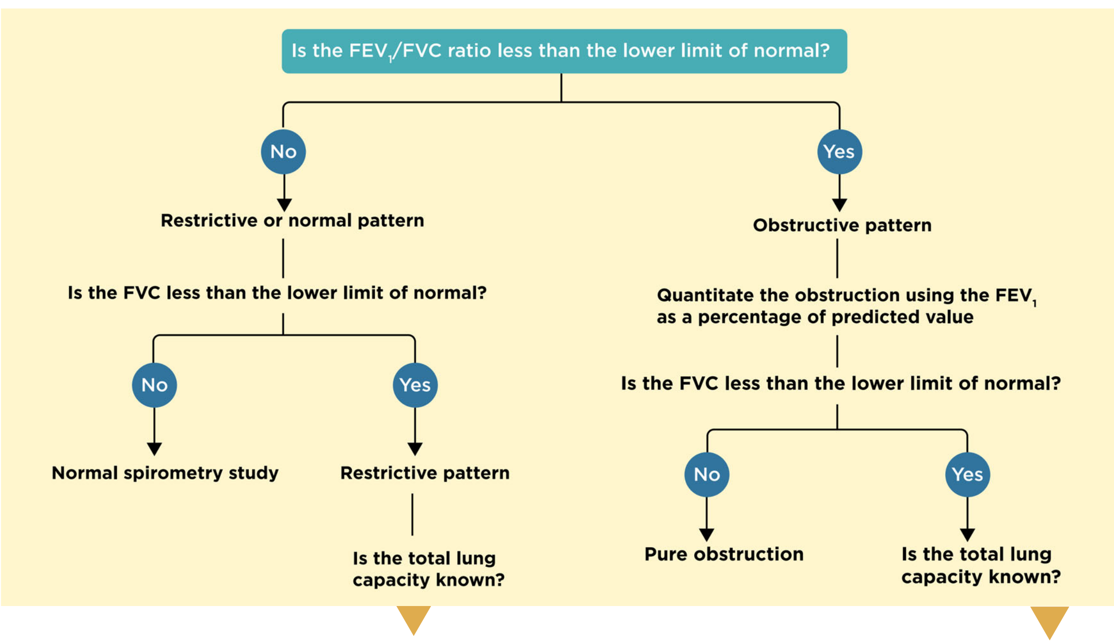
The following flowchart can be used to help interpret spirometry results. This approach involves recognizing the ventilatory defect pattern and determining its severity to support making a diagnosis.[2]

The first step is to assess the $FEV_1$/FVC ratio. When the $FEV_1$/FVC ratio is decreased, an obstructive ventilatory defect pattern is present. For an obstructive pattern, quantitate the obstruction using $FEV_1$ as a percentage of predicted value.[2]

When the $FEV_1$/FVC ratio is within normal limits, either the spirometry test is normal or a restrictive ventilatory defect pattern is present. The next step is to evaluate the FVC. If the FVC is within normal limits, then the spirometry is interpreted as being normal. If the FVC is below the lower limits of normal, then lung volumes should be obtained, if possible, before confirming if a restrictive ventilatory defect is present.

When TLC is known and below the lower limits of normal, a restrictive ventilatory defect exists and is quantified using TLC as a percentage of predicted values. If TLC is not known then the degree of restriction is quantified using the FVC as a percentage of predicted value.[2]

### Flowchart to Interpret Spirometry Test Results[2]




- If the TLC is not known, then quantitate the restriction using the FVC as a percentage of predicted value
- If the TLC is decreased, then quantitate the restriction using the TLC as percentage of predicted value
- If the TLC is normal, then the test is normal

- If the TLC is not known, there may be possible mixed obstruction and restriction
- If the TLC is decreased, there may be mixed obstruction and restriction depending on the pattern seen with RV and FRC
- For obstructive lung defects, RV and TLC can demonstrate air trapping and hyperinflation. For restrictive defects, TLC is needed to confirm true restriction and to quantitate severity

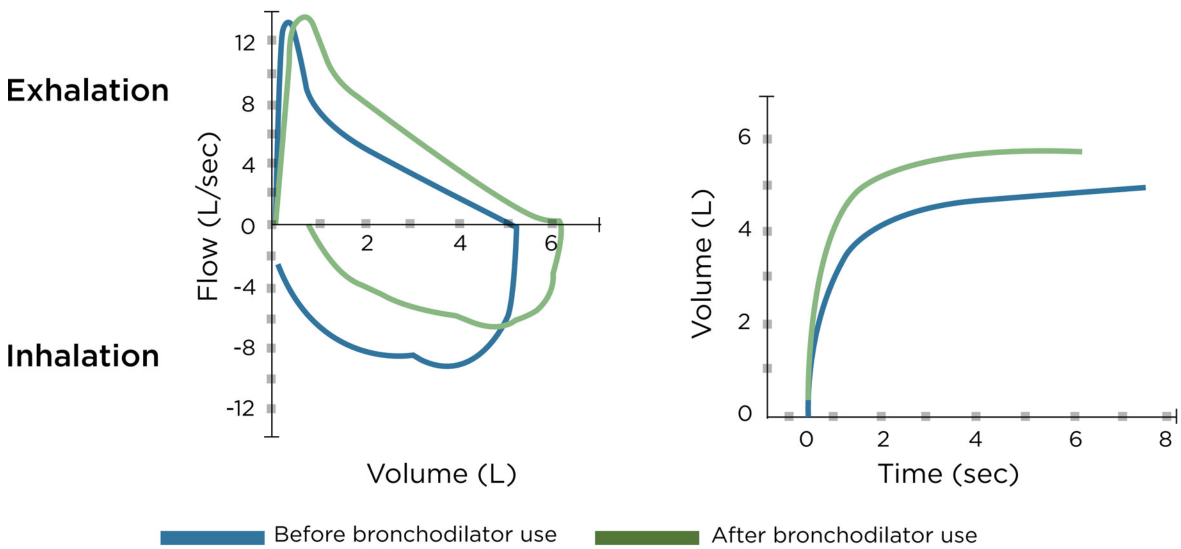
Adapted from: Al-Ashkar.[2]

## REVERSIBILITY OF AIRFLOW OBSTRUCTION

When the FVC result is decreased or normal, the $FEV_1$ result is decreased, and the absolute $FEV_1$/FVC ratio is decreased, the spirometry results identify a pattern of obstruction. It is important to assess for reversibility of the obstruction by performing a pre- and post-bronchodilator test. This assessment is used to determine if fixed airway narrowing is present. Reversibility is based on an increase of at least 12% and 200 mL in $FEV_1$ and/or FVC after bronchodilator treatment. For asthma patients, airway obstruction that is reversible is an essential diagnostic component, such as shown in the figure.[10]

Significant positive response to bronchodilator is defined by an increase in $FEV_1$ and/or FVC by at least 12% and by at least 200 mL (cc).[12]

### Reversible Airway Obstruction




Adapted from: Johnson.[10]

## SEVERITY OF LUNG IMPAIRMENT

Once the ventilatory pattern has been identified as obstructive or restrictive, the severity of the lung function impairment can be determined. The severity of obstruction is based on $FEV_1$ as a percentage of the predicted value. Similarly, the severity of restriction is based on FVC or TLC as a percentage of its respective predicted value.[2]

| Severity | $FEV_1$ or FVC % of predicted*[12] |
|---|---|
| Mild | ≥70% predicted |
| Moderate | 60-69 |
| Moderately severe | 50-59 |
| Severe | 35-49 |
| Very severe | <35 |

Adapted from: Johnson[10]; Pellegrino.[12]

*A restrictive ventilatory defect is best confirmed by a TLC that is < lower limit of normal (LLN) or < 80% of predicted.[10,12]

## BRONCHIAL CHALLENGE TEST

When spirometry test results are normal, but asthma is still suspected because a patient experiences respiratory symptoms consistent with the diagnosis, a challenge test may be performed. Bronchial challenge testing, also referred to as bronchoprovocation, is used to identify and characterize airway hyperresponsiveness (AHR).[13] AHR is an increased sensitivity and exaggerated response to stimuli that cause airway narrowing.

Some commonly used challenge agents include: methacholine, histamine, eucapnic voluntary hyperventilation (cold or room temperature gas), or exercise. A positive challenge is consistent with, but not entirely diagnostic of asthma, and must be interpreted along with other features of asthma or respiratory diseases.[14]

### Bronchial Challenge Methods

| Method | Diagnostic Capability |
|---|---|
| **Direct challenge test**<br>Methacholine mimics the neurotransmitter acetylcholine, causing bronchoconstriction and airway narrowing at a lower dose and to a greater extent in those with asthma or AHR (especially among athletes in winter sports); can also be demonstrated with histamine[14] | • $PD_{20}$ (provocative dose) expresses the delivered dose of methacholine causing a 20% fall in $FEV_1$[14]<br>• Evidence shows that $PD_{20}$ allows more consistent correlation of results than $PC_{20}$ (provocative concentration)[14] |
| **Indirect challenge test**<br>Exercise or other airway stimulus elicits bronchoconstriction by indirectly stimulating airway epithelium due to water loss (from airway drying and cooling) or osmolar change from dehydration[14] | Positive challenge result when a 10% or greater decline from baseline $FEV_1$ occurs over any 2 consecutive time points in 30 minutes after exercise[10] |

$PD_{20}$—provocative dose causing a 20% fall in $FEV_1$; $PC_{20}$—provocative concentration causing a 20% fall in $FEV_1$.

## AIRWAY RESPONSE TO METHACHOLINE[14]

| Interpretation | $PD_{20}$ µmol (µg) | $PC_{20}$ mg/mL |
|---|---|---|
| Normal | >2 (>400) | >16 |
| Borderline AHR | 0.5-2.0 (100-400) | 4-16 |
| Mild AHR | 0.13-0.5 (25-100) | 1-4 |
| Moderate AHR | 0.03-0.13 (6-25) | 0.25-1 |
| Marked AHR | <0.03 (<6) | <0.25 |

AHR—airway hyperresponsiveness.

Adapted from: Coates.[14]

## DIFFERENTIAL DIAGNOSIS

Using results from the patient's physical exam, clinical history, presence of symptoms consistent with airway obstruction, demonstration of reversible airflow obstruction upon spirometry, or a positive airway challenge test, if necessary, an asthma diagnosis may become apparent.[2]

| If the diagnosis is not asthma, but the pattern is obstructive, consider these disorders: |
|---|
| Alpha-1 anti-trypsin deficiency[10] |
| Bronchiectasis[10] |
| Bronchiolitis obliterans[10] |
| COPD[10] |
| Cystic fibrosis[10] |
| Early silicosis[10] |
| Emphysema[8] |
| Pulmonary edema[8] |
| Tumor[8] |
| Vocal cord dysfunction[13] |

| If the pattern is restrictive, consider these disorders: |
|---|
| Chest Wall: ankylosing spondylitis, kyphosis, morbid obesity, scoliosis[10], or pleural disorder[8] |
| Drug adverse reactions[10] |
| Interstitial lung disease: asbestosis, berylliosis, eosinophilic pneumonia, hypersensitivity pneumonitis, idiopathic pulmonary fibrosis, sarcoidosis, or late silicosis[10] |
| Lobectomy[8] |
| Neuromuscular disorders[10] |

## ASTHMA-COPD OVERLAP

Once non-pulmonary conditions, such as undiagnosed heart disease or vocal cord dysfunction have been excluded, patients with persistent airflow limitations after bronchodilation and current clinical and historical features of both asthma and COPD may be initially recognized as having asthma-COPD overlap (ACO).[1]

Spirometry is of limited value in differentiating ACO from COPD, as both conditions will exhibit a $FEV_1$/FVC ratio <0.70. These patients should be referred for confirmatory investigations. There are many uncertainties surrounding ACO, but it is clear that these patients have frequent exacerbations, more rapid decline in lung function, and high mortality.[1]

# FORCED EXPIRATORY VOLUME MANEUVER TIPS

For providers who desire to use an in-office portable spirometer to assess lung function, here are some tips for performing a forced expiratory volume maneuver.

## BEFORE TESTING

Please address these items before starting a forced expiratory volume maneuver:

- Calibrate spirometer[9]
- Explain test to patient[9]
- Demonstrate maneuver to patient[9]
- Record height, age, gender, and race/ethnicity[2,3]
- Record type and time of last bronchodilator use[3]

**Test results are provided as measured values and percentages of predicted values (% pred). The predicted values and lower limits of normal have been determined by regression analysis using demographic information from normal populations without lung abnormalities.[2] Therefore, a patient's predicted value is based on age, height, sex, and race/ethnicity.[4] Incorrect demographic data may affect interpretation of the results.[2]**

## DURING TESTING

Please consider these steps when performing a forced expiratory volume maneuver:

- Seat patient comfortably[3]
- Ask the patient to raise his or her head slightly[9]
- Attach nose clip and place the mouthpiece in the mouth, with the lips sealed tightly[9]
- Coach the patient to take as deep a breath as possible[9]
- Coach the patient to blast out the air as hard and as fast as possible[9]
  - For adults, the forced exhalation should last at least 6 seconds to reach a plateau[5]
  - For those with COPD, time to reach a plateau may take much longer[5]
  - For children under 10 years of age, the exhalation should last for at least 3 seconds[5]
- Repeat the maneuver with the same level of effort at least 3 times, usually no more than 8 times are required[9]

**A healthy person typically can exhale from 70% to 80% of the FVC in the first second of a forced expiratory volume maneuver.[5]**

# REFERENCES

**1.** GINA. Global Strategy for Asthma Management and Prevention, 2026. Accessed June 16, 2026. www.ginasthma.org. **2.** Al-Ashkar F, Mehra R, Mazzone PJ. Interpreting pulmonary function tests: recognize the pattern, and the diagnosis will follow. *Cleve Clinic J Med.* 2003;70(10):866-881. **3.** GOLD Spirometry for healthcare providers. Global Initiative for Chronic Obstructive Lung Disease (GOLD). Revised 2010. Available at http://goldcopd.org/wp-content/uploads/2016/04/GOLD_Spirometry_2010.pdf. Accessed June 16, 2026. **4.** Barreiro TJ, Perillo I. An approach to interpreting spirometry. *Am Fam Physician.* 2004;69:1107-1114. **5.** Respiratory health spirometry procedures manual. National Health and Nutrition Examination Survey (NHANES). Centers for Disease Control and Prevention website. January 2011. Available at https://stacks.cdc.gov/view/cdc/26507. Accessed June 16, 2026. **6.** Lutfi MF. The physiological basis and clinical significance of lung volume measurements. *Multidiscip Respir Med.* 2017(12):3-15. **7.** Criée CP, Sorichter S, Smith HJ, Kardos P, Merget R, Heise D, et al. Body plethysmography—its principles and clinical use. *Respir Med.* 2011;105(7):959-971. **8.** Wood K. Airflow, lung volumes, and flow-loop volume loop. Merck Manual Professional Version website. Available at https://www.merckmanuals.com/professional/pulmonary-disorders/tests-of-pulmonary-function-pft/airflow,-lung-volumes,-and-flow-volume-loop#v912616. Accessed June 16, 2026. **9.** Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. *Eur Respir J.* 2005;26(2):319-338. **10.** Johnson JD, Theurer WM. A stepwise approach to the interpretation of pulmonary function tests. *Am Fam Physician.* 2014;89(5):359-366. **11.** Johns DP, Pierce R. Spirometry: the measurement and interpretation of ventilatory function in clinical practice. Thoracic Society of Australia and New Zealand. March 2008. **12.** Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, et al. Interpretive strategies for lung function tests. *Eur Respir J.* 2005;26(5):948-968. **13.** EPR-3. Expert panel report 3: guidelines for the diagnosis and management of asthma. NIH publication no. 07-4051. Bethesda, MD: U.S. Department of Health and Human Services; National Institutes of Health; National Heart, Lung, and Blood Institute; National Asthma Education and Prevention Program. August 2007. Available at https://www.nhlbi.nih.gov/health-topics/guidelines-for-diagnosis-management-of-asthma. Accessed June 16, 2026. **14.** Coates AL, Wanger J, Cockcroft DW, Culver BH and the Bronchoprovocation Testing Task Force. ERS technical standard on bronchial challenge testing: general considerations and performance of methacholine challenge tests. *Eur Respir J.* 2017;49(5):1601526. **15.** Aboussouan LS, Stoller JK. Flow-volume loops. In: UpToDate, Connor RF (Ed), Wolters Kluwer. Accessed June 16, 2026.