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Focus on Diagnosis : Spirometry

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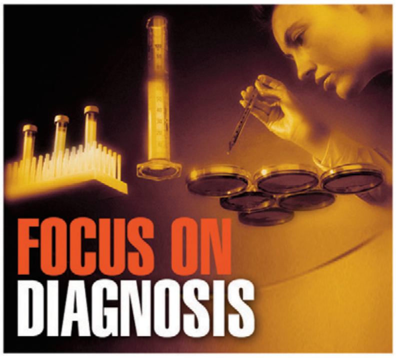

Spirometry

Kamakshya P. Patra, MD

Author Disclosure
Dr Patra has disclosed no financial relationships relevant to this article. This commentary does not contain a discussion of an unapproved/investigative use of a commercial product/device.

Abbreviations

$FEF_{25\%-75\%}$:	forced expiratory flow, midexpiratory phase
FEV_1:	forced expiratory volume fraction in 1 second
FVC:	forced vital capacity
PEFR:	peak expiratory flow rate

Introduction

Office spirometry, traditionally done by the pulmonary specialist, has become commonplace in the pediatric primary care office. The National Asthma Education and Prevention Program guidelines recommend routine use of spirometry for the initial diagnosis and ongoing management of asthma. A nationwide survey demonstrated that only 21% of physicians used spirometry for the management of children with asthma, as per the guidelines. And, approximately one half of the physicians were unable to interpret the results of spirometry. Office spirometry has been shown to result in change in asthma management in 15% of children. In 45% of cases, the severity of asthma was underrated by the providers in the absence of spirometry. A peak flow meter, which measures peak expiratory flow rate (PEFR), is a simple, inexpensive, and portable device that may be helpful in the management of asthma. However, PEFR is effort-dependent and does not reflect small airway function. The average cost of a good spirometer is in the $1,500 to $2,000 range. There must be training of the office personnel who perform the spirometry, and the spirometer should be calibrated at least daily. In general, patients must be at least age 4 to 4.5 years to perform reliable forced vital capacity (FVC) maneuvers required for spirometry.

Case Study

A 7-year-old girl has experienced wheezing since age 3 years and has been diagnosed as having asthma. Her symptoms did not improve despite therapy with albuterol, corticosteroids, salmeterol, and monteleukast. She was referred to the pediatric pulmonology clinic for persistent symptomatology. Spirometry was performed, which revealed a fixed obstruction. Flow volume loops revealed truncation of inspiratory and expiratory limbs (Fig 1). Computed tomography scan of the chest revealed double aortic arch. Surgery resulted in resolution of symptoms.

This case vignette underscores the importance of spirometry in the management of asthma. Spirometry helps the provider rule out diseases that can masquerade as asthma, such as vocal cord dysfunction, which may be mislabeled as refractory asthma. In these cases, flow volume loop will reveal attenuated inspiratory limb (Fig 2). No improvement in forced expiratory volume fraction in 1 second (FEV_1) with administration of a bronchodilator should be a clue that asthma is unlikely.

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Indications of Spirometry

Office spirometry, when done properly, is valuable in the diagnosis and management of acute and chronic respiratory symptoms and can serve a number of functions:

- To differentiate lung disease into obstructive and restrictive disorders.
- To provide objective evaluation of the response to therapy.
- To guide withdrawal of treatment.
- To do a preoperative evaluation, especially before lung surgery.
- To rule out other wheezing disorders that can mimic asthma.

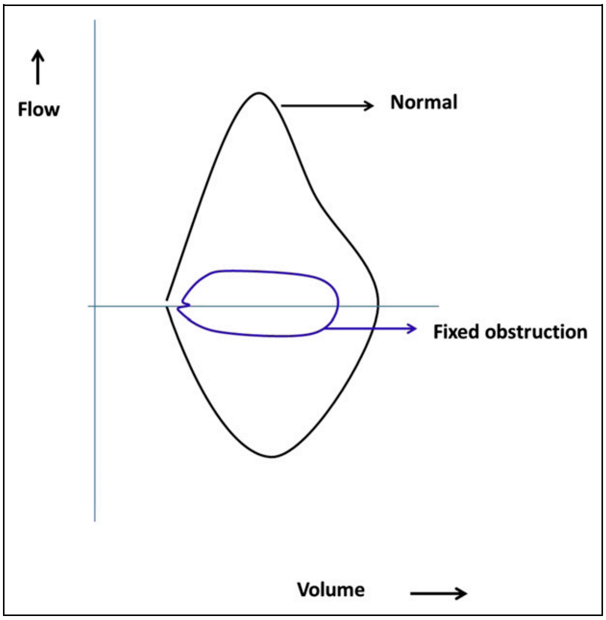

Figure 1. Flow volume loop configuration in fixed obstruction. Loop above line is expiratory loop; loop below line is inspiratory.

Optimizing Performance

The child should be made familiar with the spirometry instruments, the procedures that will be done, and the personnel. The mouthpiece may be given before practice for holding and blowing correctly. Nose clips might be helpful. The child's head and torso should be erect during the maneuver.

The child should be asked to breathe slowly to a maximal inhalation, followed by a breath hold for 1 to 2 seconds, and then sustained exhalation for at least 3 seconds. The test should include a minimum of three reproducible curves. Difference in values <5% indicates reversibility. The largest FEV_1 and FVC are measured, even if these results are from two different curves.

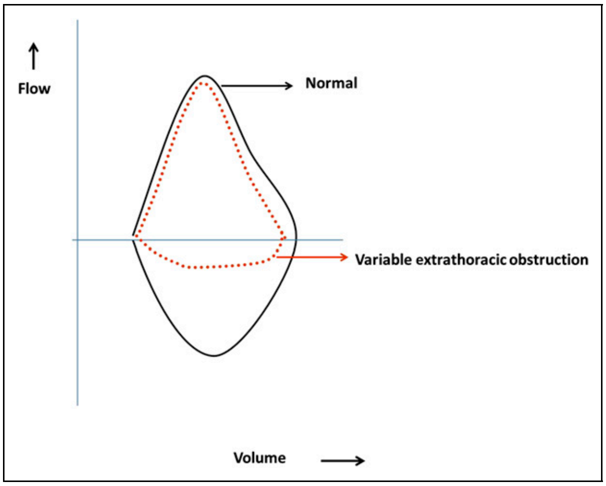

Figure 2. Flow volume loop configuration in variable extrathoracic obstruction. Loop above line is expiratory loop; loop below line is inspiratory.

Interpretation

Proper interpretation of spirometric parameters must take into account variables that include age, gender, race, and standing height. The spirometer should conform to the American Thoracic Society standards. Results are usually given in both absolute data and percent predicted for the patients of similar characteristics (age, gender, height, ethnicity, etc). Findings should be compared with the patient's baseline ("personal best") values.

The following lung volumes help in understanding spirometry and are depicted in Fig 3.

- Tidal volume: the volume of air either inspired or expired during normal effortless respiration.
- Inspiratory reserve volume: the volume of air inspired by forcible inspiration after normal inspiration.
- Expiratory reserve volume: the volume of air expired by forcible expiration after normal expiration.
- Residual volume: the volume of air remaining in the lungs at the end of maximal expiration.
- Total lung capacity: the volume of air contained within the lungs after a forcible inspiration.
- Inspiratory capacity: the volume of air inspired by forcible inspiration.
- Functional residual capacity: the volume of air remaining in the lungs at the end of normal exhalation.

Spirometry cannot measure functional residual capacity and total lung capacity.

The key parameters measured in spirometry are FVC, FEV_1, and forced expiratory flow, midexpiratory phase ($FEF_{25\%-75\%}$). The volume time graph depicts these parameters

Ne sont pas mesurable par la spirométrie:
- FRC = Capacité Fonctionnelle Résiduelle
- TLC = Capacité pulmonaire Totale

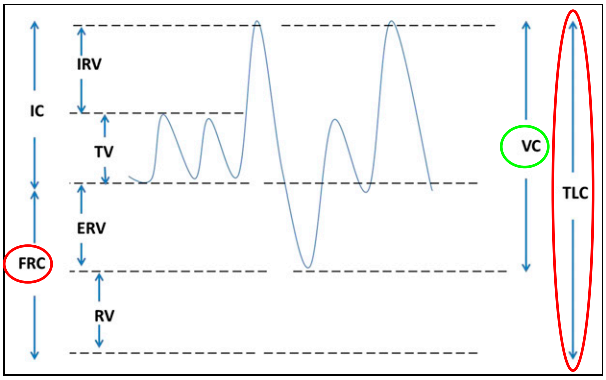

Figure 3. Time volume curve depicting FEV_1, FVC, and $FEF_{25\%–75\%}$. ERV=expiratory reserve volume; FRC=functional residual capacity; IC=inspiratory capacity; IRV=inspiratory reserve volume; RV=residual volume; TLC=total lung capacity; TV=tidal volume; VC=vital capacity.

(Fig 4). A glossary of the common spirometric indices is given below.

- FVC is the maximal volume of air expired forcefully after a forcible inspiration.
- FEV_1 is the fraction of FVC expired during the first second.
- FEV_1 to FVC is referred to as forced expiratory ratio.
- The forced expiratory volume in 6 seconds is sometimes used as a surrogate for FVC.
- $FEF_{25\%–75\%}$ is measured from the FVC curve by excluding the first 25% and last 25% of expiratory flow. This measurement evaluates small airways. A decrease in $FEF_{25\%–75\%}$ is evident before changes in FEV_1, PEFR, and clinical signs or symptoms.

Obstructive and restrictive disorders can be differentiated by spirometric findings. FEV_1, FEV_1/FVC, and $FEF_{25\%–75\%}$ are decreased in obstructive disorders. FVC is decreased in restrictive disorders (interstitial lung disease, structural diseases of the chest wall, neuromuscular disorders, etc). FVC may be decreased also in severe obstructive lung disease due to air trapping. Therefore, FEV_1 rather than FEV_1/FVC should be used in assessing the severity of obstructive lung disease because FVC also decreases with the severity of obstruction. FEV_1/FVC ratio is normal in restrictive lung diseases (≥80%).

Specific disorders will produce distinct patterns in the parameters measured by spirometry.

Asthma
Low FEV_1, a FEV_1/FVC ratio <0.8, postbronchodilator increase of 12% in FEV_1 or 200 mL, low FEV_1, decline in FEV_1 > 15% post exercise, diurnal variation of FEV_1 or peak expiratory flow >20% are the characteristic features of asthma.

Cystic Fibrosis
Patients who have cystic fibrosis show an obstructive pattern on spirometry with progression of disease. Acute exacerbations are associated with a decrease in FEV_1 and a return back to baseline with adequate treatment. Superimposed restrictive changes are a late finding in cases of interstitial fibrosis. FEV_1 <30% of baseline suggests the need for transplant evaluation.

Flow Volume Loop
In flow volume loop diagrams, inspiratory and expiratory flow (on the *Y* axis) is plotted against volume (on the *X* axis). The curve above the line represents expiration, whereas the curve below the line depicts inspiration, forming a loop, and the direction of the loops is clockwise (Figs 1, 2, and 5). The configuration of the loop can yield information about the type of lung disease (Fig 5).

Lower Airway Obstruction
Obstructive lung disease alters the shape of the loop, whereas the restrictive lung disease alters the size of the loop. Intrathoracic obstruction causes concavity or "scoop" in the expiratory limb of loop (Fig 5).

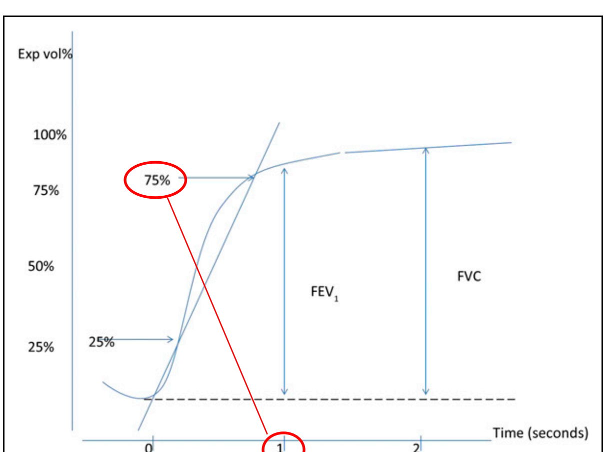

Figure 4. Spirographic divisions of lung volume and capacity.

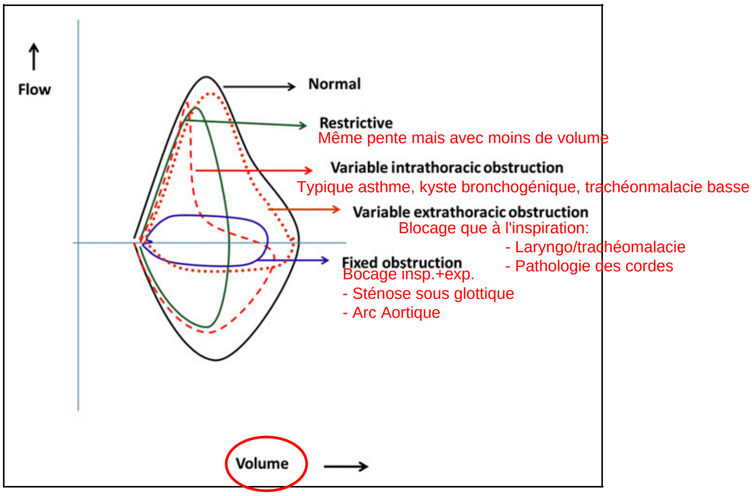

Figure 5. Flow volume loop configurations in normal and different pulmonary disorders. Loop above line is expiratory loop; loop below line is inspiratory.

Upper Airway Obstruction

- Variable extrathoracic obstruction may be caused by laryngomalacia, tracheomalacia of the extrathoracic trachea, and vocal cord pathologies. There is flattening of the inspiratory limb of the loop without altering the expiratory limb (Fig 2).
- Variable intrathoracic obstruction can be caused by tracheomalacia of the intrathoracic trachea, bronchogenic cyst, etc. The flow volume loop reveals attenuation of the expiratory limb without changing the inspiratory limb (Fig 5).
- Fixed obstruction is caused by subglottic stenosis from prolonged intubation, goiter, etc. It causes truncation of both inspiratory and expiratory limbs in the flow volume loop (Fig 1).

A saw-tooth pattern on the flow-volume loop is produced by fluttering during the expiratory or inspiratory phase and often is seen in obstructive sleep apnea.

Peak Expiratory Flow

Peak expiratory flow meter testing can be performed in children older than 4 years of age because this testing does not require sustained expiration. Suited to home monitoring, the peak expiratory flow meter provides a reproducible and objective measurement for triaging and guiding therapy. However, the test is effort-dependent, and there is a wide variation in reference values.

Serial measurements are more useful than a single reading. Less than a 20% diurnal variation indicates good control of asthma. Decline in PEFR may be a harbinger of an attack of asthma, which is helpful in the management of "poor perceivers." Average cost of a peak expiratory flow meter is approximately $50.

PEFR is monitored twice daily (best of three attempts) for several weeks to find the individual's personal best. The child is coached to take a deep breath in and blast out. A traffic stoplight color-coded zone system based on the child's personal best is utilized to guide intervention. Green zone (80%–100% of personal best) implies effective control. Yellow zone (50%–80% of personal best) indicates less than optimal control and necessitates more frequent therapy. Red zone (<50% of personal best) suggests an emergency situation.

Suggested Reading

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