Spirometry in Chronic Obstructive Lung Disease (COPD)

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Introduction

The common criterion recommended for diagnosis of chronic obstructive lung disease (COPD) is demonstration of “progressive irreversible airway obstruction” on spirometry. The Global Initiative for Chronic Obstructive Pulmonary Disease (GOLD) has recommended spirometry as the gold standard for diagnosis of COPD. However, spirometry is not widely available and spirometric test results are not always optimally recorded or interpreted except when performed by experienced personnel. Experts have differed on spirometric criteria for diagnosis of COPD. GOLD now recommends that post bronchodilator forced expiratory volume in 1 second/forced vital capacity (FEV1/FVC) ratio of <0.70 must be used for diagnosing COPD. Demonstration of “irreversible airway obstruction” i.e. absence of bronchodilator reversibility is no more required for diagnosis of COPD. Although there is now a consensus; spirometric criteria continue to have limitations. The simplification of spirometry criteria by GOLD experts is perhaps to encourage spirometry for diagnosis of COPD in primary-care settings worldwide. However; widespread spirometric testing has resulted in a large number of individuals without respiratory symptoms, labeled as COPD. On the other hand physicians continue to diagnose COPD based solely on symptoms. Individuals with symptoms but normal spirometry were earlier included as “at risk” for COPD. The revised GOLD guidelines do not include this group as there is incomplete evidence that these cases always progress to COPD. The United States Preventive Services Task Force, an independent panel of experts in primary care and prevention that systematically reviews the evidence of effectiveness and develops recommendations for clinical preventive services suggest spirometry evaluation in a person presenting with shortness of breath, chronic cough, increased sputum production, wheezing, and/or a family history of alpha1-antitrypsin deficiency. A combination of symptoms and spirometry may therefore be a more relevant way of diagnosing COPD in individuals exposed to the causative factor.

Role of spirometry in COPD requires basic understanding of spirometry, its importance in the management of COPD with knowledge of how to perform spirometry correctly and its interpretation (Chart). American Thoracic Society and European Respiratory Society guidelines (ATS/ERS guidelines) are used for acceptable and reproducible spirometry. Factors such as cough, variable effort, sudden cut off, slow start, inconsistent effort are some of the criteria that may result in fallacies. Spirometry is useful in COPD for the following:

- Diagnosis
- Assessment of severity
- Assessment of response to therapy
- Assessment of lung age
- Detection of upper airway obstruction
- Pre-operative pulmonary evaluation

Diagnosis

A typical spirogram (volume versus time recoding) and flow volume loop –FVL (flow rate versus volume recording) in COPD is as shown in Figures 1 and 2. The interpretation of obstruction in the spirometry report however remains highly controversial. The current diagnostic criterion for airflow obstruction in COPD is a post bronchodilator ratio of FEV1/FVC <70%. Although COPD cases usually have no or poor bronchodilator reversibility (Exercise 1), it is well known and recognized by GOLD guidelines that some cases may show good bronchodilator reversibility (Exercise 2). The predicted FEV1/FVC ratios decrease progressively with age in adults. A fixed FEV1/FVC ratio thus overestimates airflow obstruction in the elderly and underestimates it in young adults. Obstructive abnormality is most accurately diagnosed when a reduced FEV1/FVC ratio is below lower limit of normal (LLN) i.e. the 5th percentile of the predicted value. The post-bronchodilator reference values that are required for accurate interpretation of spirometry have not yet been developed. False normalization of the FEV1/FVC ratio that occurs due to a greater reduction in FVC caused by air trapping in severe airflow obstruction may result in a tendency to diagnose a restrictive ventilatory abnormality and thus more severe cases being missed (Exercise 3). Therefore spirometry-based diagnosis of COPD and the “one size fits all” spirometric criteria are inappropriate.

COPD patients have an inability to perform a complete or adequate exhalation, resulting in an underestimate of FVC and

![Chart: Interpretation of Spirometric Data](image)

- Volume in liters
- Time in Seconds
- Normal
- Obstructive abnormality
- Restrictive abnormality

Fig. 1 : Graphic display of volume versus time spirogram (obstruction in COPD –dotted lines).
overestimate of FEV$_1$/FVC ratio. For this reason the measurement of the forced expiratory volume in 6 seconds (FEV$_6$) has been advocated along with the FEV$_1$/FEV$_6$ ratio. In such patients additional useful information can be obtained by measuring the subdivisions of lung volume. The primary measurement is functional residual capacity (FRC) with a slow vital capacity maneuver, and estimation of other lung volumes. Elevated ratio of residual volume (RV) to total lung capacity (TLC) suggests airflow obstruction. The diffusion capacity of the lung for carbon monoxide (DLCO) decreases in the presence of emphysema. Small airway function in COPD can be assessed with the measurement of airway resistance (Raw) using body plethysmography and total respiratory system resistance (Rs) with forced oscillation technique (FOT) or impulse oscillometry (IOS). However, in day to day clinical practice a well performed spirometry with clinic-radiological correlation is sufficient for diagnosis of COPD.

**Assessment of Reversibility with Aerosolized Bronchodilators**

ATS/ERS guidelines significant reversibility is considered to be an increase in FEV$_1$ of 200ml and 12% after 15 minutes of bronchodilator therapy. Bronchial asthma shows good reversibility with bronchodilators whereas COPD often shows poor reversibility. Therefore, traditionally, reversibility testing has been used to distinguish COPD from bronchial asthma. However studies have shown a wide range of reversibility in clinically well defined COPD. This was verified in the UPLIFT (Understanding Potential Long Term Impacts on Function with Tiotropium) trial, which included at baseline a reversibility test with a combination of high dose ipratropium and salbutamol. A majority of patients (53.9%) reached the ATS/ERS threshold of reversibility. Roughly 30% of patients with COPD show significant reversibility and reversibility is greater severe <30, “rule of 30-50-80” (Table 1). Airway obstruction in COPD can be variable which is based on varying degree of smooth muscle contraction. This can be reversed by administering an inhaled bronchodilator. Hence, the GOLD criteria for COPD are based on post bronchodilator reversibility values. Also there is no need for the patient to stop regular treatment prior to post bronchodilator spirometric measurements. COPD being progressive disease leads to worsening of lung function over time. The normal decline of FEV$_1$ ie 30 ml/year gets accelerated in COPD patients to 75 to 100 ml/year. COPD is now recognized to have systemic manifestations that are not reflected by the FEV$_1$. Hence, a simple multidimensional grading system the BODE (body mass index, obstruction, dyspnoea, and exercise tolerance) index (Table 2) has been used to assess the respiratory and systemic expressions of COPD. The BODE staging system also helps to better predict hospitalization for COPD.

**Assessment of Severity**

GOLD recommends that the assessment of severity of COPD be based on a physiological variable, post bronchodilator FEV$_1$% predicted as mild>80, moderate 50-80, severe 30-50 and very
with anticholinergic therapy. Conversely, asthma shows poor reversibility with chronicity and airway remodeling. Hence, bronchodilator reversibility is not a useful criterion for diagnosis of COPD and has been removed in the recent GOLD update.

Use of corticosteroids to test reversibility in COPD has also not been recommended.

Assessment of Lung Age

Smoking is attributed as the main cause of COPD. A key indicator of COPD is a reduced FEV1 compared with predicted FEV1 value. Hence, spirometry is a gold standard for diagnosis of COPD. It can also be used for assessing the “lung age” (measured FEV1) of the patient of COPD as compared to the predicted FEV1 as per his chronological age. This can illustrate the likely negative impact of continued smoking on lung function. Demonstration of graphic illustration e.g. 45-year old man with COPD with a “lung age” of an 80 year old is shown in figure 3. Estimation of lung age is also helpful in encouraging smokers to quit smoking. In the Lung Health Study, 6000 middle age smokers were randomized to smoking cessation program and followed for 5 years. Sustained quitters had a rate of decline of FEV1 of 31ml/year compared with 62ml/year in those continued to smoke.

Detection of Upper Airway Obstruction (UAO)

The most common etiology for COPD being smoking, these patients are at high risk of laryngeal, pharyngeal and lung malignancies. Spirometric flow volume loop assessment helps to identify evidence of upper airway obstruction, helping in prioritizing management plans. Flow volume loop is a graphic expression of flows at different lung volumes. It helps in identifying variable as well as fixed UAO at various levels (Figure 4a, b, c). Miller and Hyatt defined three classic patterns of flow volume loop contours (Figure 5) in the patients with upper airway obstruction, depending on the location of the obstruction and whether the obstruction was fixed or variable. UAO can be diagnosed by clinical and radiological correlation along with inspection of the pattern of flow volume loop and calculation of indices.

Empey’s index: FEV1 in ml/Peak expiratory flow (PEF) in L/min

<table>
<thead>
<tr>
<th>Class</th>
<th>Severity</th>
<th>FEV1 / FVC</th>
<th>FEV1 (Postbronchodilator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Mild</td>
<td>&lt;70%</td>
<td>&gt; 80</td>
</tr>
<tr>
<td>II</td>
<td>Moderate</td>
<td>&lt;70%, 50%</td>
<td>50% - 80%</td>
</tr>
<tr>
<td>III</td>
<td>Severe</td>
<td>&lt;70%</td>
<td>30% - 50%</td>
</tr>
<tr>
<td>IV</td>
<td>Very Severe</td>
<td>&lt;70%</td>
<td>&lt;30 % or 30% - 50% + Right Heart Failure</td>
</tr>
</tbody>
</table>

Table 1: Classification of Severity (GOLD Guidelines)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 (%Predicted)</td>
<td>&gt; 65</td>
</tr>
<tr>
<td>Walk Distance in 6 min (m)</td>
<td>&gt; 350</td>
</tr>
<tr>
<td>MMRC Dyspnea Scale</td>
<td>0-1</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>&gt; 21</td>
</tr>
</tbody>
</table>

Table 2: BODE Index Predicts Mortality

Normal, non susceptible smoker

![Fig. 3: Figure showing method of assessment of lung age.](image)

![Fig. 4a: Figure showing mechanism for variable extrathoracic upper airway obstruction (VEUAO).](image)

![Fig. 4b: Figure showing mechanism for variable intrathoracic upper airway obstruction (VIUAO).](image)
Indices of UAO

- FEV1 (ml) / PEF (L / m) = > 8 (Empey’s index)
- FEF50 / FIF50 = <0.3 or > 1

Fig. 5: Figure showing upper Airway Obstruction (UAO): Flow volume loop interpretation.

\[ \frac{\text{FEF} 50}{\text{FIF} 50} \] (ratio of flow at 50% of expiration and flow at 50% of inspiration)

Indices further help confirm presence and identify the type of UAO.

- Presence of UAO is indicated by Empey’s index \( > = 8 \).
- Type is determined by:
  - \( \frac{\text{FEF} 50}{\text{FIF} 50} = 1 \) in fixed UAO
  - \( \frac{\text{FEF} 50}{\text{FIF} 50} > 1 \) in variable extrathoracic upper airway obstruction
  - \( \frac{\text{FEF} 50}{\text{FIF} 50} < 0.3 \) in variable intrathoracic upper airway obstruction

Patients with severe COPD, even a significant tracheal stenosis may not be apparent on flow volume loop and also FEV1 is a poor indicator of large airway obstruction. If COPD patients develop variable extrathoracic UAO, compromising the inspiratory flow, it is easy to diagnose. But if it is variable intrathoracic upper airway obstruction, it is difficult as both COPD and variable intrathoracic UAO cause expiratory flow changes. Effort dependent high flow portion of flow-volume loop near TLC is the first to be distorted in the UAO. Patients presenting with obstructed main bronchus (Figure 6a) show “biphasic flow volume loop” or “two can effect” due to slow emptying and filling of the affected lung (Figure 6b).

Role of Spirometry in Pre-Operative Pulmonary Evaluation

COPD is a well known independent risk factor for the development of post operative pulmonary complications after thoracic or non thoracic surgery. It should be performed in patients requiring thoracic surgery or in non thoracic (particularly thoracic or upper gastro intestinal surgery) only if history of tobacco smoking, cough, dyspnoea are present and if clinical or radiological findings suggest pulmonary abnormality.

Thoracic surgery

Role of spirometry is well defined in pre-operative evaluation of thoracic surgery. Predicted postoperative (ppo) values should be calculated by deducting the volume to be resected from the pre-operative values. For this purpose “rule of five” can be
used which assumes one-fifth function for each lobe. A simpler method is the “rule of fives”, where one fifth function is attributed to each lobe. Postoperative FEV₁ is calculated by deducting the volume contributed by the lung to be resected. For example, if the preoperative FEV₁ is 2.5 liters and a right upper lobectomy is planned (1/5 of 2.5), i.e. 0.5 liters is deducted from 2.5 liters which gives a predicted postoperative FEV₁ of 2 liters (Exercise 4). Perfusion scans may be performed to determine exact contribution of the lobe/lung to be resected. Predicted postoperative FEV₁ less than 40% predicted contraindicates any lung resection.

Non thoracic Surgery

Spirometry is not routinely indicated in non thoracic surgeries. Pre-operative evaluation is done to assess the risk of postoperative pulmonary complications and to minimize them by optimal treatment. Smoking cessation for at least 8 weeks prior to surgery and vigorous pulmonary hygiene in the 48 to 72 hours before surgery along with optimized bronchodilator therapy helps to reduce postoperative pulmonary complications in COPD. In patients with COPD, FEV₁/FVC less than 50%, maximum voluntary ventilation <50%, or a high PaCO₂ place the patient at a higher risk for postoperative complications. National Emphysema Treatment Trial (NETT), FEV₁ or DLCO underdiagnosis of COPD: results of the IBERPOC multicentre epidemiological study. Chest 2000;118:981-989.


References

2. Crapo RO, Jensen RL. Standards and interpretive issues in lung function testing. Respir Care 2003;48:764-772.