



Spirometry: All You Need to Know

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PULMONARY FUNCTION TESTING

Pulmonary function testing include the following tests

1. Tests for ventilation: Spirometry with helium dilution technique
 - Body plethysmography
2. Test for diffusion: Diffusion capacity for carbon mono-oxide (D_{LCO})
3. Tests for ventilation perfusion: Ventilation / perfusion (V/Q) scan
 - Nitrogen wash out test (N_2 ws)
4. Exercise testing
6. Arterial blood gas analysis
7. Bedside tests: Peak expiratory flow (PEF), transcutaneous O_2
 - (SpO_2) and CO_2 (tCO_2) monitoring
8. Tests for respiratory muscle function: PI max and PE max
9. Tests for respiratory center function: CO_2 stimulation test
10. Tests for sleep related respiratory disorders: polysomnography (PSG)

Of all the above tests spirometry is the most basic and widely used method of evaluating pulmonary functions.

SPIROMETRY

Spirometry is the measure of airflow during inspiration and expiration. It can easily be performed in the physician's consulting room, with simple and affordable equipments called spirometers. The test is performed in the sitting position (by convention) and airflow is recorded as forced and sustained expiration followed by forced and sustained inspiration. Three efforts, which have less than 5% variability between each other, are selected and the best effort is used for interpretation. Routinely, only expiratory flow may be recorded before and after administration of bronchodilators i.e. two puffs of salbutamol (100 mcg each). However, both expiratory and inspiratory recordings are required for evaluation of upper airway obstruction.

Uses of Spirometry

Spirometry is useful for the following:

- Evaluation of cases with respiratory symptoms

- Assessment of severity of respiratory disorders
- Assessment of response to therapy
- Pre operative pulmonary evaluation
- Detection of pulmonary functional abnormality in predisposed individuals e.g. occupational exposures, neuromuscular, chest wall, or upper airway disorders

Spirometric Equipment

Several spirometers are available commercially. Selection depends on the cost and individual requirement. American Thoracic Society (ATS) recommends that the equipment should be such that it meets the minimum standards i.e.

- should record 7 litres volume and 12 L/second flow rate
- should be calibrated with a 3 L syringe
- should record minimum FVC and FEV_1 and
- should record flow volume curve or flow volume loop or both.

American Thoracic Society (ATS) Recommendations for Performing Spirometry

- Effort Maximal, smooth, and cough-free
- Position Sitting
- Exhalation time 6 seconds
- End of test 2 second volume plateau
- Reproducibility FVC within 5% in three acceptable tests

Spirometric Measurements

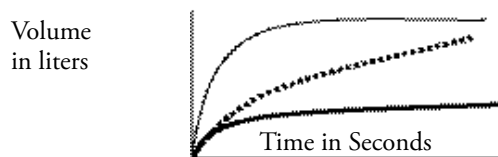
The spirometric recording is represented in two forms, absolute values and graphic forms.

Absolute values: (Fig. 2)

- The total volume of air expired with a maximal effort is the forced vital capacity (FVC) in litres.
- The volume of air expired in first second is the forced expiratory volume (FEV_1) in litres.
- The maximal expiratory flow rate in mid portion of expiration i.e. (25%-75%) is the maximal mid expiratory flow rate (MMFR) or MEFR (25%-75%) in L /sec or L/Min

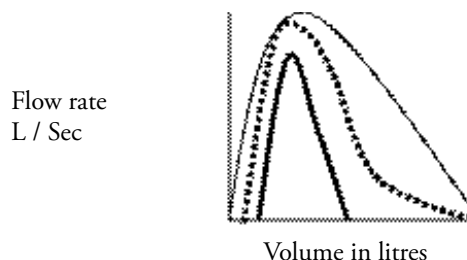
SPIROMETRIC RECORDINGS

- Spirogram: Graphic display of volume versus time:

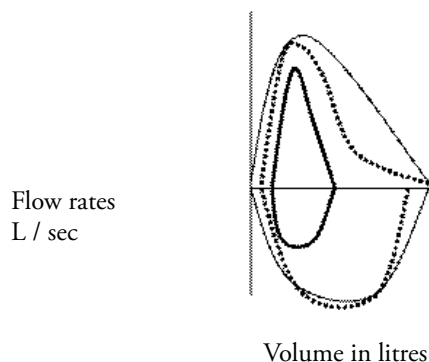


- Flow rate versus volume: Graphic display of flow rate versus volume

Flow volume curve (only expiratory recording)



Flow volume loop when inspiratory flow is also recorded



Normal
 Obstructive abnormality
 Restrictive abnormality

Fig. 1: Spirometric Recordings

- The maximal flow during first 10 seconds of expiration is the peak expiratory flow rate (PEFR) in L/sec or L/ Min.

The flow is also recorded graphically (Fig. 1)

- Volume versus time : spirogram or timed vitalograph
- Flow rate versus volume : flow volume curve / loop

Interpretation of Spirometric Data: (Fig. 3)

Diagnosis and Fallacies

Spirometry is only a diagnostic aid and should be interpreted only with clinical and radiological correlation. Values recorded on different equipment and by different technicians may vary considerably. The same degree of functional abnormality on spirometry may result in different degrees of disability in different

Fig. 2 : Spirometric Data

- The minimum parameters required for spirometric interpretation are
- FVC : Forced vital capacity
- FEV₁ : Forced expiratory volume in 1 second
- MMFR (MEFR25-75) : Maximal mid-expiratory flow rate
- PEFR : Peak expiratory flow rate

All the above parameters are read as normal or abnormal when compared to predicted values. Predicted values vary as per age, sex, height and ethnic groups, are obtained by large-scale studies in the community and are readily available for use. Value above 75% of predicted are generally considered as normal.

patients. Two basic types of pulmonary function abnormalities are described using the basic spirometric parameters, obstructive and restrictive.

Obstructive and Restrictive Abnormalities

Obstructive

Airway disorders such as asthma, chronic obstructive pulmonary disease (COPD), bronchiectasis, etc.

$$FEV_1\% = FEV_1 (\text{observed}) / FEV_1 (\text{predicted}) < 80\%$$

$$FEV_1 / FVC \% = FEV_1 (\text{observed}) / FVC (\text{observed}) < 75\%$$

When clinical evaluation suggests airway obstruction low FEV₁% predicted suggests an obstructive abnormality. Severity can be graded as 60%-80% mild, 40%-60% as moderate and less than 40% as severe. Good bronchodilator reversibility (BDR) is considered when improvement in FEV₁ by 200ml and >12%, both occur after a dose of bronchodilator.

FEV₁/FVC on the other hand does require predicted values as both FEV₁ and FVC are patient's recorded values. This ratio is an accurate diagnostic parameter for obstructive abnormalities. However false normalization of FEV₁/FVC may occur in moderate to severe airway obstruction caused by marked fall in FVC due to air trapping. There is a normal age-related decline in the FEV₁/FVC ratio; so normal elderly patients without airway obstruction will have a ratio below 70-80%. Also low FEV₁/FVC may occur due to reduction in forced expiratory volume alone in the earlier stages of neuromuscular disorders and may be misdiagnosed as airway obstruction.

The various flow rates like MMFR, PEFR are reduced to less than 75% of their predicted values in obstructive disorders. The importance of recording and noting an initial PEFR value is that it can be used for long term monitoring particularly in cases of bronchial asthma. PEFR recording can be done on peak flow meters, which are cheap, portable and easy to use.

Example of spirometry demonstrating obstructive abnormality:

	Observed	Predicted	%Pred
FVC	2.5	3.15	79
FEV ₁	1.15	1.55	74
FEV ₁ /FVC	50	75	

Restrictive

Chest wall, pleural, and lung parenchymal diseases.

$$FVC \% = FVC (\text{obs}) / FVC (\text{pred}) < 75\%$$

FVC is dependent on the patient's performance; therefore reduced FVC does not diagnose but only suggests a restrictive abnormality,

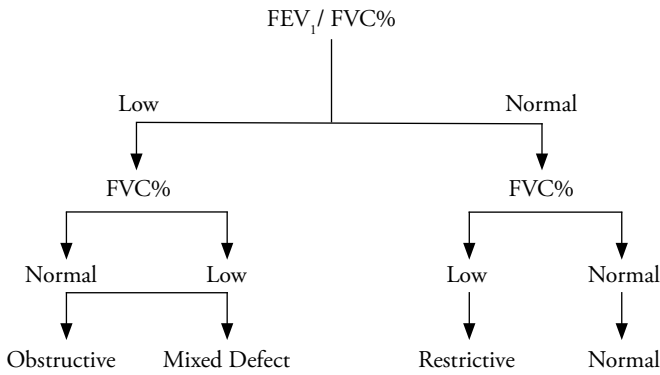


Fig. 3: Interpretation of Spirometric Data

which should be correlated clinically and radiologically. Reduction in FVC may occur due to air trapping in moderate to severe airway obstruction. Measurement of residual volume (RV) and total lung capacity (TLC) using helium dilution technique or body plethysmography may be used to confirm restrictive abnormalities. However, in practice interpretation of spirometric data with clinical correlation is usually adequate.

Example of spirometry showing restrictive abnormality:

	Observed	Predicted	%Pred
FVC	1.7	3.38	52
FEV ₁	1.53	1.90	80
FEV ₁ /FVC	90	75	

Upper Airway Obstruction (UAO): (Fig. 4)

Obstruction of upper airways results in upper airway obstruction (UAO). Upper airways extend from the nose / mouth to the carina. Diagnosis of UAO requires recording of both inspiratory and expiratory flow and displaying them as flow volume loops. The inspiratory or expiratory or both phases of the loop are flattened and the indices of UAO are positive.

Indices of UAO

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

(FEF50 is forced expiratory flow at 50% or mid expiration, and FIF50= forced inspiratory flow at 50% or mid inspiration)

Accordingly, UAO is of two types

Fixed UAO: when there is no variability in upper airway obstruction during inspiration and expiration. Examples of fixed UAO are strictures and stenosis of the trachea. The flow volume loop shows a "box like" pattern with both inspiratory and expiratory curve flattening. The Empey's index is greater than 8 and the ratio of FEF50 / FIF50 equals 1.

Variable UAO: when the upper airway obstruction is in the extrathoracic or intrathoracic portion of the upper airways causing greater narrowing during inspiration or expiration respectively.

Variable extrathoracic UAO: when obstruction is in the extrathoracic portion of upper airway e.g. pharyngeal and laryngeal tumours, vocal cord paralysis and enlarged thyroid compressing the trachea. The flow volume loop shows greater

**UPPER AIRWAY OBSTRUCTION (UAO):
FLOW VOLUME LOOP INTERPRETATION**

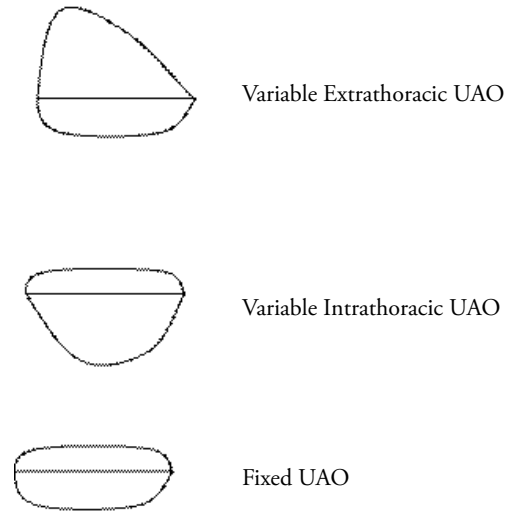


Fig. 4: Interpretation of Spirometric Data

Indices of UAO

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

flattening of the inspiratory portion. Empey's index is positive and ratio of FEF50 / FIF50 is greater than 1.

Variable intrathoracic UAO: when obstruction is in the intrathoracic portion of upper airway e.g. tracheal tumours and mediastinal masses compressing on the intrathoracic portion of trachea. The flow volume loop shows greater flattening of the expiratory portion. Empey's index is positive and ratio of FEF50 / FIF50 is less than 0.3.

Role of spirometry in pre-operative pulmonary evaluation:

- Pulmonary function testing is not routinely indicated for pre-operative evaluation.
- Spirometry should be performed in patients requiring lung resection surgery
- Or in surgery other than lung resection (particularly thoracic or upper gastro intestinal surgery) only if
 1. History of tobacco smoking, cough, dyspnoea
 2. Clinical or radiological findings suggest pulmonary abnormality

Lung resection surgery

- Role of spirometry is well defined in pre-operative evaluation of lung resection 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.
- Perfusion scans may be performed to determine exact contribution of the lobe/lung to be resected.

- ppo FEV₁ less than 40% predicted contraindicates any lung resection.

Surgery other than lung resection

- Pre-operative evaluation is done to assess the risk of postoperative pulmonary complications and to minimize them by optimal treatment.
- Patients described as high risk by PFT can undergo surgery with an acceptable risk for postoperative pulmonary complications.

- Risk is indirectly proportional to the distance of surgical site from the thorax.

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