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Pulmonary Function Tests-Relevance to Anesthesiologists

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Review Article

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Abstract

Pulmonary function tests are non-invasive tests to study the lung function. They measure lung volume, capacity, rates of flow, and gas exchange. Spirometry measures rate of air flow and lung size, lung volume tests accurately measures how much volume lungs can hold, pulse oximetry helps estimates oxygen level in the blood, lung diffusion capacity measures how well oxygen gets into blood on inhaling air into lungs, and arterial blood gas analyses the level of gases such as oxygen and carbon dioxide in blood stream. This review article summarizes a brief review of pulmonary function testing and its relevance to anesthesiologist.

Keywords: Pulmonary function tests; Lung function; Spirometor

Introduction

Pulmonary function tests provide objective, quantitative measurement of lung function. It is also known as respiratory function testing. Lung function is used to know major important functions such as: Ventilation, Perfusion, Diffusion, Lung mechanics, Evaluate obstructive diseases that affect heart and lung function, to monitor effects of environmental, occupational and drug exposure and to assess lung function in evaluation performed for employment or insurance purposes.

Aims & Objectives

- For basic physiological knowledge of pulmonary function in healthy individuals & factors affecting them (i.e age, sex & weight)
- To know the type , extent & progression of disease
- To check for reversibility of disease pre- operatively
- Anticipated intra & post-operative problems
- To evaluate fitness for job
- At the time of weaning

Factors Prompting Preoperative PFT'S

- Age > 70 years
- Morbid obesity
- Thoracic surgery/lung resection
- Cardiac surgery
- History of smoking/cough/dyspnea
- Uncharacterized pulmonary symptoms

Limitations

- Variability in normal predicted values
- Trained technician [1]
- Active patient participation
- Inability to interpret the results

Classification

PFTs can be divided into:

- Clinical or bed side
- Static- RV, TV, IRV,ERV
- Dynamic- MVV, FVC, FEV1
- Biochemical- ABG
- Newer- flow volume loops

PFTs can be done under:

I. General practice: bedside + PEFR
II. Hospital practice: PFT by spirometry, pulmonary arterial occlusion
III. In referral centre: body plethosmography

Bed Side Pft's

On examination: Orthopnea, dyspnea, cyanosis, decrease in chest excursions, chest wall retraction, accessory muscles of respiration, tracheal tug etc.

History: daily activity, talking time- whether patient is able to finish his sentence in one breath or has to catch his breath.

Tests [2]

a) **Forced expiratory time**: it is done for obstructive diseases; patient has to take a deep breath and then exhale as forcibly and completely as possible through mouth. Normally it is completed in 3 seconds. Prolongation is abnormal in obstructive cases. Severity can be judged by time taken to complete.

b) **Sabrasez breath holding test:** patient is asked to take a deep breath while at rest and to hold it.

- Normal is > 40 sec.
- mild 20-25 seconds
- moderate 15-20 seconds
- severe <15 seconds

c) **Snider's match blowing test / Modified Snider's test**: it is an indirect measure of FEV1.
Patient is asked to extinguish a lit match held at 15 cm distance with mouth open and nose pinched. It reflects MBC > 60L/min, FEV1 > 1.6 L. If the patient is not able to extinguish at 8 cm, reflects FEV1 <1.6 L, MBC <40 L/minute.

d) **Seberese's single breath count** >30 is suggestive of normal cardio- pulmonary reserve.

e) **Debono's whistle**: it measures the expiratory force, patient is asked to blow down a side bore tube, one end of which is a whistle inside. There are adjustable holes, the whistle blows when the rate of inflow through the tube exceeds. Subject is asked to take maximum inspiration, closes his lip around mouth piece, avoiding leaks and exhales as rapidly as possible. The size of hole is increased stepwise till maximum expiratory force cannot affect whistle. The expiratory flow rate is then read on calibration of the instrument. If patient can blow whistle with maximum leak, suggests good function.

f) **Sphygmanometer blow test (endurance test)**: patient is asked to blow and raise column of mercury upto 40-50 mmHg, and duration for which the patient can hold at that level is noted, 50 seconds is considered normal.

g) **Greene & Berowitz cough test:** patient is asked to cough vigorously. Dry cough is considered normal, normal cough production is 30cc/day. Wet self-propagated productive cough is suggestive of post-operative complications.

h) **Wright's peak flowmeter:** it measures peak expiratory flow (PEF), also called peak expiratory flow rate (PEFR). A small, hand-held device used to monitor a person's ability to breathe out air.

i) **Watch & stethoscope test**: auscultate over trachea, if expiration is <3 seconds, respiratory obstruction is less likely. Forced expiratory time is normally 4 sec, >6 seconds is suggestive of respiratory obstruction.

j) **Ability to talk constantly or climb 1-2 flight of stairs**

- FEV1 = 3.2 L (80% of VC) is normal
- FEV1 >1.5 L moderate exercise tolerated
- FEV1 1-1.5 L breathlessness
- FEV1 <1 L breathlessness on slight exerton

h) Others:

- **Blowing a balloon**
- **Spirometry with pocket sized spirometer**
- **Exercise capacity tests**-Stair climbing test, Exercise oximetry, 6 min walking test
- **Wright's Respirometer**: TV, MV

Another important PFT is ABG, which measures the value of Po2 and PCO2 in the blood.

Measurement of Lung Volumes

1. Spirometric volume determinations: tidal volume, IRV, ERV, IC, VC, not RV [3]
2. Gas dilution
a. Multibreath nitrogen washout technique
b. b. Helium dilution technique (Body plethysmography also for RV, FRC)
3. Nitrogen washout technique: Closing capacity

Static Lung Tests

1. **Tidal Volume**: volume of air moving in and out of lungs during quiet respiration, it is about 6-8ml/kg, or about 500 ml.
2. **Inspiratory Reserve Volume:** maximum volume that can be inhaled from end inspiratory position. It is about 3.1-3.6 Liters
3. **Expiratory Reserve Volume**: is the maximum volume of air that can be exhaled from end expiratory position and is about 1.2 liters
4. **Residual Volume**: is the volume of air remaining in lungs after maximal exhalation. It is not measured by spirometry and is indirectly measured from FRC- ERV, and is about 1200 ml.
5. **Inspiratory Capacity**: TV + IRV normally it is about 3500 ml
6. **Functional Residual Capacity**: is the volume of gas remaining in lungs after passive expiration. FRC= RV + ERV. It ranges between 1.8-3.4 liters. Body plethysmography is the gold standard for measuring FRC. Other methods include helium dilution technique and nitrogen washout method.
7. **Vital Capacity**: is the largest volume of air that can be expired after forceful inspiration. VC= IRV + TV + ERV
8. **Total Lung Capacity**: maximum volume to which lungs can be expanded with greatest inspiratory efforts. TLC = VC+ RV and is normally about 5800 ml.
9. **Closing Capacity**: is the point at which smaller airways begins to collapse during expiration.

Dynamic Lung Function Tests: They attempt to quantitate the pulmonary ventilation in terms of rate at which ventilation takes place [4].

a. **Maximum Breathing Capacity**: is the maximum volume that can be breathed per minute.
b. **Maximum Voluntary Ventilation**: is the largest volume that can be breathed per minute by maximum voluntary efforts. For measuring this, patient is asked to breath as hard and fast as possible for 12-15 seconds and same is extrapolated for 60 seconds. Ideally it should be measured for one minute, but for prevention of hypocapnea, it is measured for 12-15 seconds and is expressed as L/minute. It co-relates well with FEV_1.
c. **MVV = FEV_1 × 35** and is about 100-200 L/minute. It is decreased in old age, pulmonary emphysema, bronchospasm, obstruction etc.
d. **Forced Vital Capacity**: FVC is a test where a patient needs to expire as hard and fast in the spirometer as possible. The results of the test are compared to the predicted values that are calculated from his age, size, weight, sex and ethnic group. It is characterized by an initial full inspiration to TLC, followed by abrupt onset of expiration to residual volume. The expiration should be at least 4 seconds and should not be interrupted by coughing, glottis closure or mechanical obstruction.

Forced Expiratory Volume In One Second (FEV_1)

The volume expired in the first second of the FVC test is called **FEV_1** (Forced Expiratory Volume in the first second) and is a very important parameter in spirometry.

The FEV_1% is the FEV_1 divided by the VC (Vital Capacity) times 100: **FEV_1%=FEV_1/VC X100.**

This parameter is also known as the **Tiffeneau index**, named after the French physician that discovered the **FEV_1/VC ratio.** Nowadays FEV_1/FVC X 100 is also accepted as FEV_1% (FEV_1/FVC ratio) (Figure1).

- A healthy patients expires approximately 80% of all the air out of his lungs in the first second during the FVC maneuver. A patient with an obstruction of the upper airways has a decreased FEV_1/FVC ratio.
- A FEV_1% that is too high is suggestive for a restriction of the pulmonary volume.
- 3-4.5 L is considered as normal, 1.5-2.5 L mild to moderate obstruction, <1 L is severe obstruction.

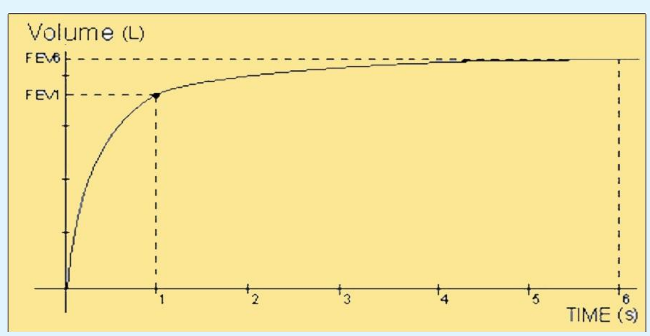

Figure 1: Co-relation between FEV_1 and FVC.

Slow Vital Capacity

This test resembles the FVC. The difference is that the expiration in the spirometer is done slowly. The patient inspires fully and then slowly expires all the air in his lungs (Inspiratory Vital Capacity) or the other way around: the patient expires fully and inspires slowly to a maximum (Expiratory Vital Capacity) (Figure 2).

- Even if the patient has expired fully, there is always some air left in the lungs. This is the Residual Volume.
- The Total Lung Capacity is equal to the (F)VC + the Residual Volume (Figure 3).
- The Residual Volume is about 20-25% of the Lung Capacity.
- If the VC is different from the FVC a collapse of the small airways is suspected (if both tests were performed correctly).

It is impossible to measure the RV with a spirometer. More sophisticated methods like the helium dilution test or body plethysmography are needed to measure the RV.

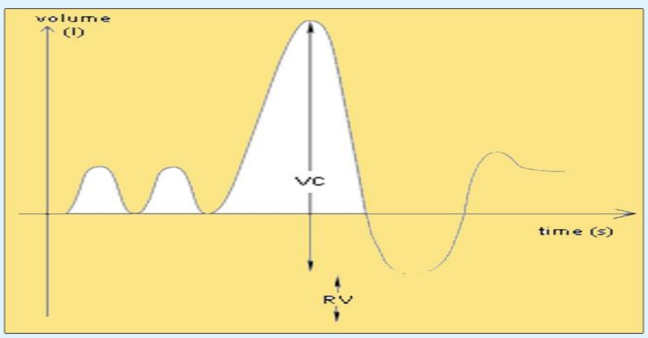

Figure 2: Predicting SVC.

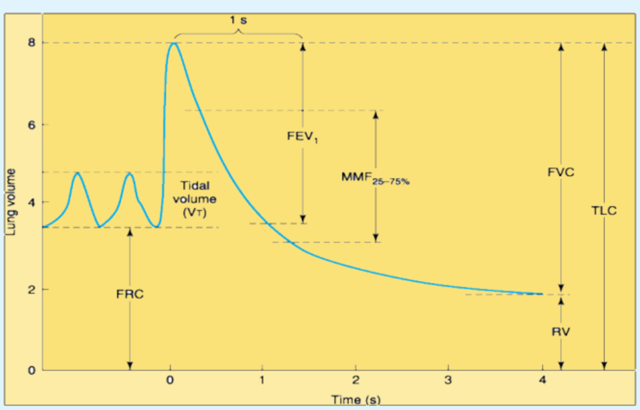

Figure3: Predicting lung Volumes.

Peak Expiratory Flow Rate

A peak flow meter is a mechanical device in which the patient blows out. The force of the expiration pushes an indicator. The higher the flow is, the farther the meter is pushed. It is important to always use the same peak flow meter to be able to compare results.

- There are different types and models of peak flow meters available. The most widely used is the 'Wright peak flow meter'. The patient inspires as deeply as possible, takes the device in his mouth and blows out as strongly and as fast as he can. It is not necessary to blow out as long as possible, in contrast to a spirometry test. An expiration of 1 second is sufficient. The test is repeated at least three times and the best value is withheld.
- Peak flow is compared to predicted values or even better - to the patient's best personal value.
- Predicted values are dependent of sex, age, height and ethnicity. A peak flow measurement measures per definition only one parameter. The peak flow is a parameter that can vary significantly and is very effort dependent (Figure 4).

1. Forced Vital Capacity: Abnormal if < 80% of predicted value
2. FEV_1: Normal = 3-4.5 L
3. FEV_1/ FVC: Normally = 75-80% FVC. It has many clinical applications (Figure 5).
4. Peak flow rate: initial 0.1s
 Normally ≥ 500 L/min
 Impaired cough if <200 L/min

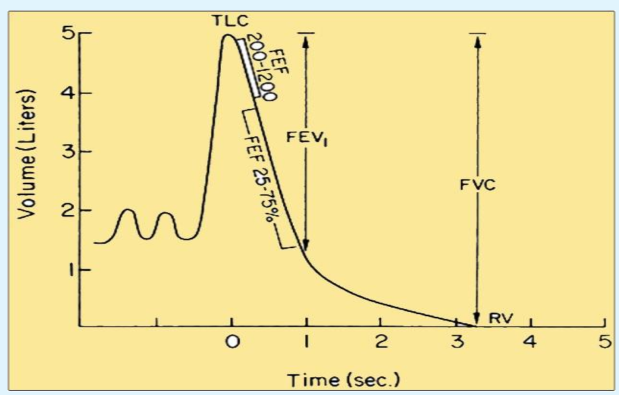

Figure 4: Peak Expiratory Flow Rate.

5. $FEF_{200-1200}$ / Max expiratory flow
6. $FEF_{25-75\%}$ / Forced midexpiratory flow:
- Effort independent

- Normally= 4.5-5L/s
- Sensitive indicator of early airway obstruction
- Maximum Breathing Capacity/Maximum Voluntary Ventilation:
- Peak ventilation available to meet physiological demand **= [FEV_1] X 35 = 150-175 L/min**

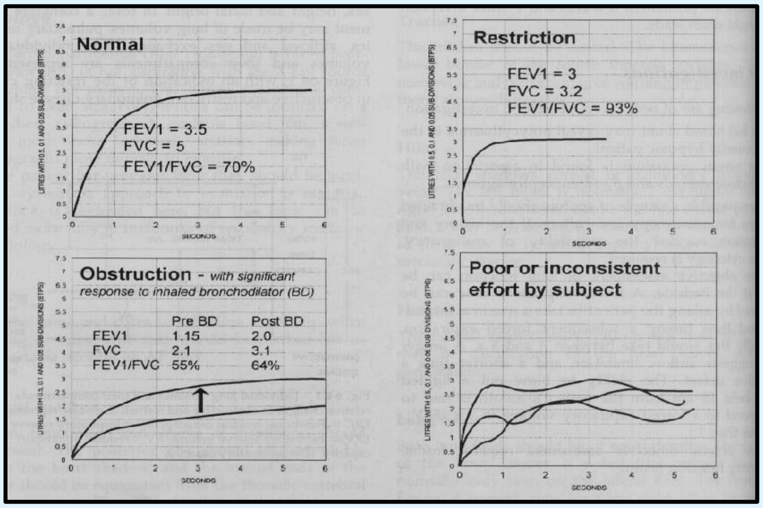

Figure 5: Forced Expiratory Maneuvers.

Flow Volume Loop

1. Provides graphic analysis of flow at various lung volumes - & are used to discriminate among patients with upper airway obstruction [5] (Figures 6-9).
2. Obstructed lung disease – flow ↓ at lower lung volumes, flow vol loop takes on a scooped out appearance.
3. Restrictive disease – relatively normal peak expiratory flow, linear ↓ in flo, lung vol is ↓- miniature flow volume loop.
4. Obstruction of the upper airway & trachea – flat ovoid loop.

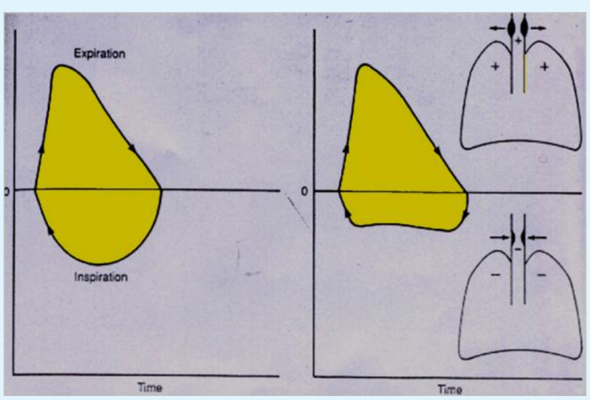

Figure 6: Flow Volume loop.

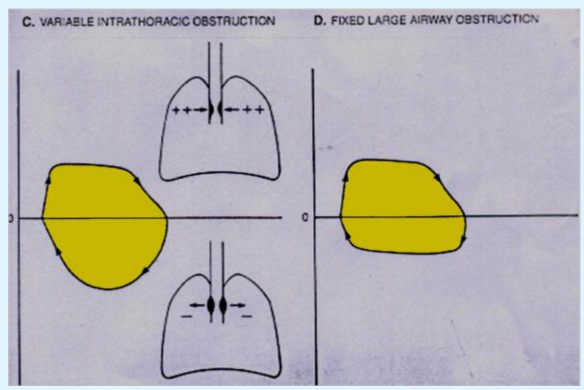

Figure 7: Flow Volume loop.

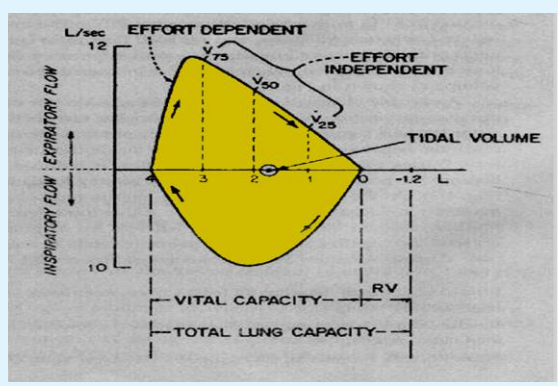

Figure 8: Flow Volume loop.

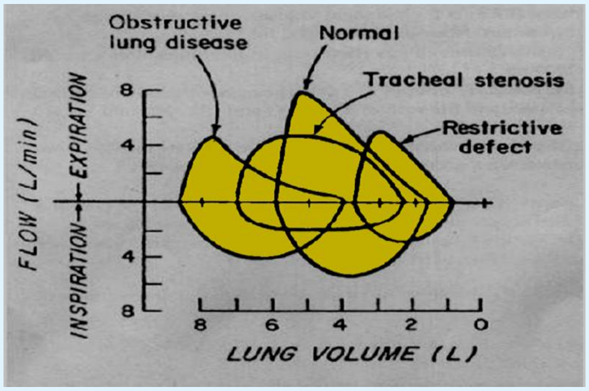

Figure 9: Flow Volume loop.

Respiratory Muscle Strength

PI max → - 125 cm of H_2O

- Severe disability to take deep breath →≤ - 25 cm of H_2O

PE max → + 200 cm of H_2O

- Severe disability to cough → ≤+ 40 cm of H_2O

Gas Exchange Function

1. Alveolar arterial oxygen tension difference: 8-12 mm of Hg at room air in young patients, 25-38 mm of Hg by 8^{th} decade.
2. Dyspnea differentiation index: PEFR × PaO_2/1000
3. Pulmonary patients → Lower DDI than cardiac patients
4. Diffusing capacity of the lungs (D_L) estimates the transfer of oxygen from alveolar gas to RBC.
5. The factors determining the D_L are Area, Thickness & Driving pressure

- Measurement: Single breath CO test
- Normal: 20 to 30 ml/min/mmHg

Conclusion

Pulmonary function testing is an important tool in investigating patients with respiratory disease. They provide important information of large, small airways, pulmonary parenchyma, size and integrity of pulmonary capillary bed. Interpreting test results require knowledge of normal values and appearance of flow volume curves, combined with patient's history and examination in preoperative assessment.

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