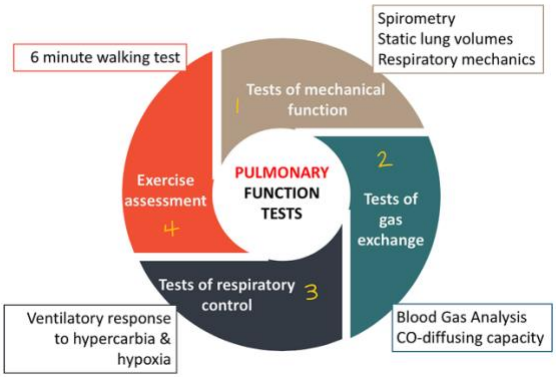
Pulmonary Function Tests Interpretation

Saneesh P J
saneeshpj@yahoo.com
http://www.OnlineAnesthesiaTOOLS.com

What are Pulmonary Function Test (PFT)s?

Pulmonary function tests (PFTs) is a term used to indicate a group of studies or maneuvers that may be performed using standardized equipment to measure lung function. PFTs can include simple screening spirometry, formal lung volume measurement, diffusing capacity for carbon monoxide, and arterial blood gases.

1. Tests of Mechanical Function
    a. Spirometry: VC, FVC, FEV1, IC, maximum inspiratory and expiratory flow rates
    b. Static lung volumes
    c. Respiratory mechanics
        Respiratory muscle strength
        i. Maximum inspiratory and expiratory mouth pressures
        ii. Maximum transdiaphragmatic pressure (Pdi max)
        Elastic recoil of lungs and chest wall
        Respiratory resistances
        Bronchial provocation testing
2. Tests of Gas Exchange
    a. Blood gas analysis
    b. Carbon monoxide-diffusing capacity (transfer factor)
3. Assessment of Respiratory Control
    Measurements of the ventilatory responses to hypercapnia and hypoxia
4. Exercise Assessment
    The Six-Minute Walking Test.



Criteria for good PFT?

1. Lack of artifact induced by coughing, glottic closure, or equipment problems (primarily leak).
2. Satisfactory start to the test without hesitation.

3. Satisfactory exhalation with six seconds of smooth continuous exhalation and/or a plateau in the volume time curve of at least one second or a reasonable duration of exhalation with a plateau.

Criteria for reproducibility after obtaining three acceptable spirograms include:

1. Largest FVC within 0.2 L of next largest FVC.
2. Largest FEV1 within 0.2 L of next largest FEV1.

If the two above criteria have not been met, additional spirograms should be obtained. (Note: Beyond eight efforts, fatigue may play a role in the results and the interpretation of the test may not be reliable.)

A reasonable end-point for the maneuver in the absence of true flow cessation (ie, airway obstruction is present) is 15 seconds. Patients often discontinue the forced exhalation prematurely because of the discomfort of prolonged forced exhalation. A modified technique in which the patient exhales with maximum force for four seconds followed by continued relaxed exhalation has been shown to enhance the patient's ability to sustain expiration, thereby yielding a larger FVC in patients with airflow obstruction.

Contraindications for Spirometry

There are no absolute contraindications for performing PFTs. Relative contraindications for spirometry include:

- Hemoptysis of unknown origin
- Pneumothorax
- Recent myocardial infarction
- Unstable angina pectoris
- Thoracic, abdominal and cerebral aneurysms
- Recent abdominal or thoracic surgical procedures
- Patients with a history of syncope associated with forced exhalation
- Recent eye surgery (raised intraocular pressure during forced expiration).

Spirometry

Spirometry is the timed measurement of dynamic lung volumes during forced expiration and inspiration to quantify how effectively and how quickly the lungs can be emptied and filled. Spirometry is used to establish baseline lung function, evaluate dyspnea, detect pulmonary disease, monitor effects of therapies used to treat respiratory disease, evaluate respiratory impairment, evaluate operative risk, and perform surveillance for occupational-related lung disease. The measurements usually made are the vital capacity (unforced and/or forced – VC, FVC), forced expiratory volume in one second (FEV1) and the ratio of these two volumes (FEV1/FVC). The flow volume loop also may be plotted. Additionally, one can measure the maximum expiratory flow over the middle 50% of the vital capacity (FEF25–75%) which is a sensitive index of small airway function. A further spirometric measure undergoing renewed interest is that of inspiratory capacity (IC) which is the maximum volume of air that can be inspired from the end of quiet expiration (FRC) to total lung capacity (TLC). IC is reduced when hyperinflation is present or develops dynamically, e.g. during exercise in COPD patients. Measures of forced maximal flow during expiration and inspiration flow can also be made, either absolutely, e.g. peak expiratory flow (PEF) or as a function of volume thus generating a flow volume curve, the shape of which also contains information of diagnostic value.

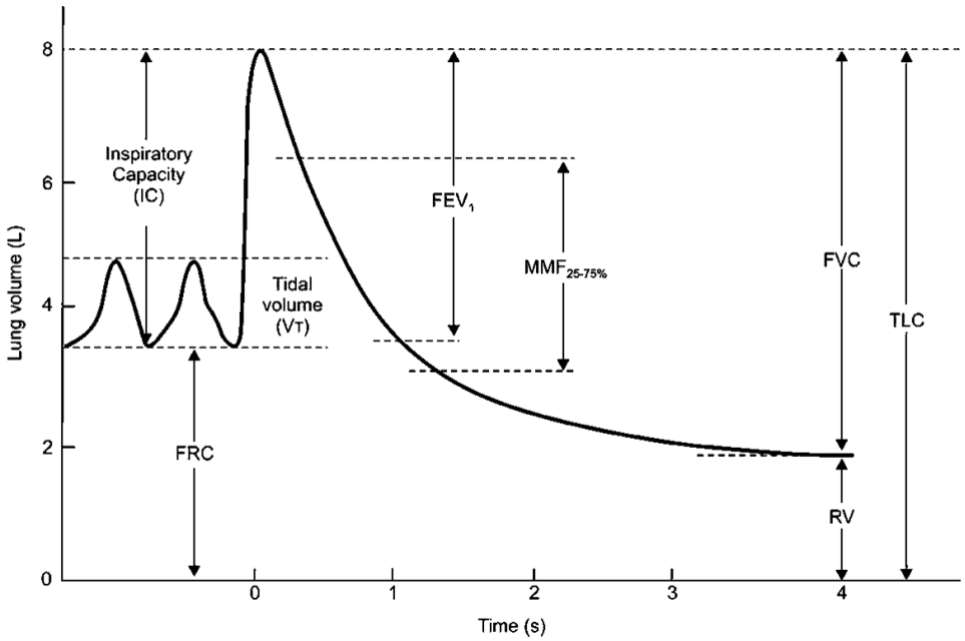
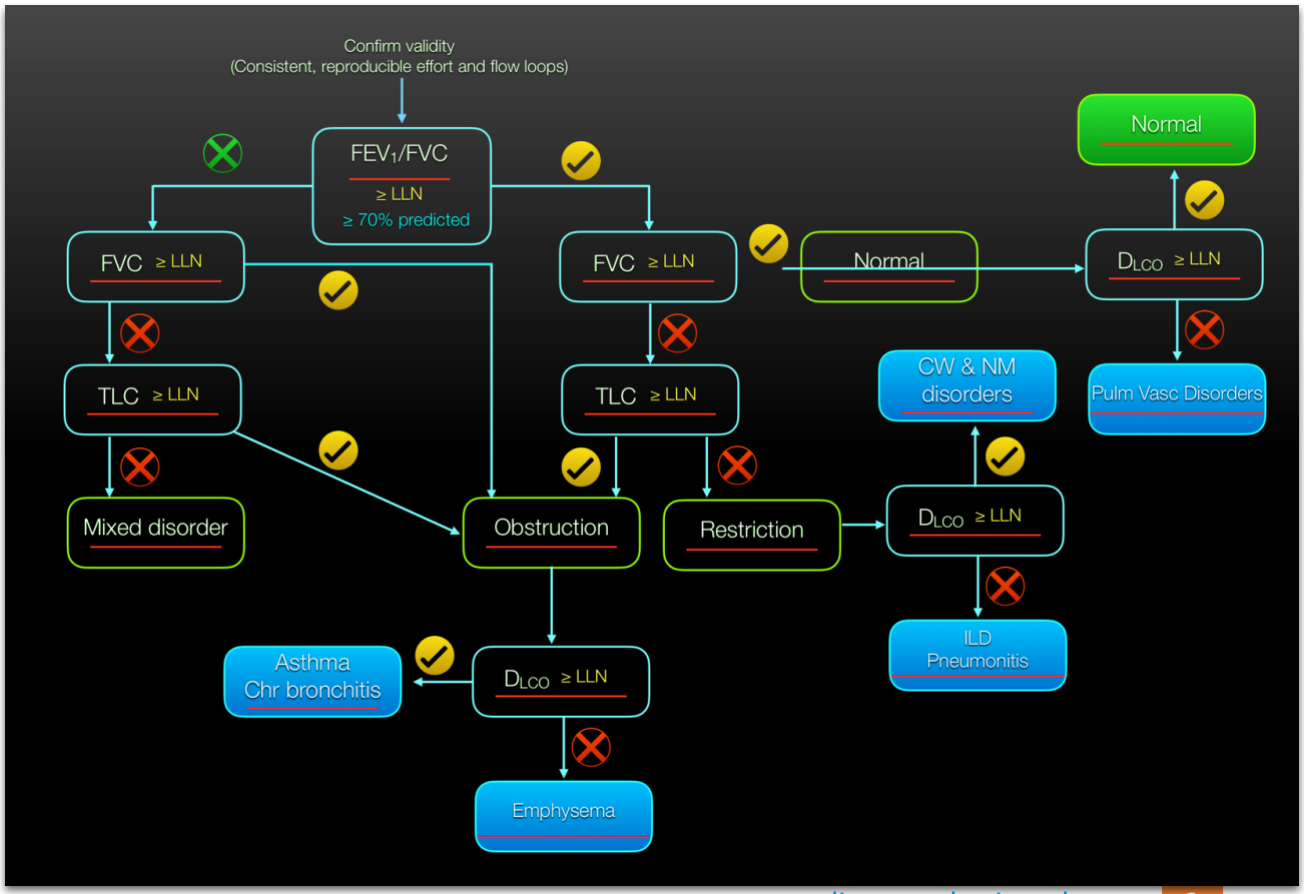
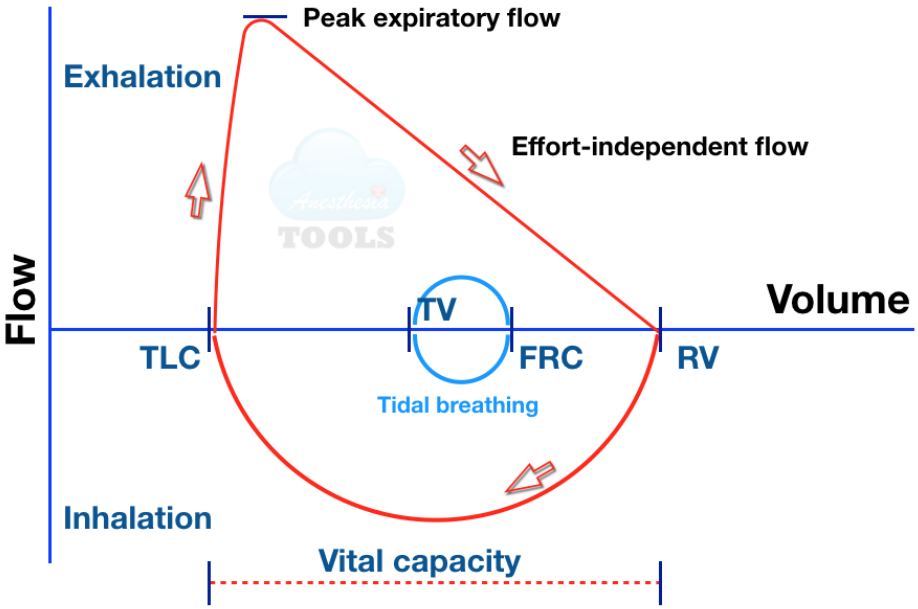


Fig: Spirogram (Volume-time curve) – measures respired volume against time
Abbreviations: TLC – Total Lung Capacity; RV – Residual Volume; FVC – Forced Vital Capacity; FRC – Functional Residual Capacity; FEV1- Forced Expiratory Volume in first second

Algorithm for PFT interpretation

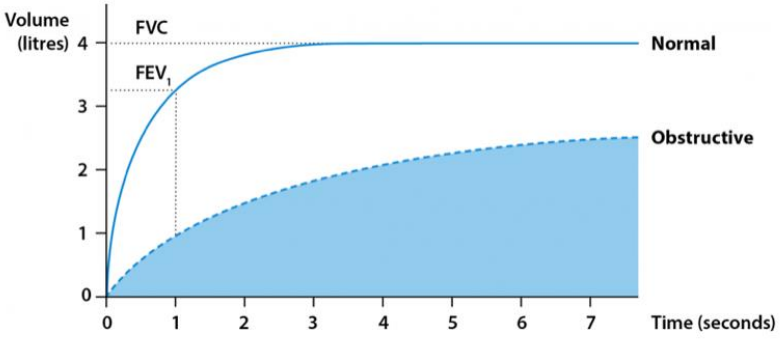


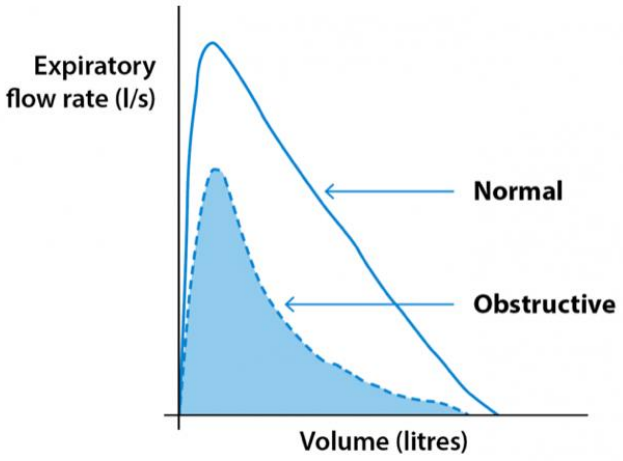
Flow-volume loop



TLC- Total Lung Capacity; TV- Tidal Volume; FRC- Functional Residual Capacity; TV – Tidal Volume; RV- Residual Volume

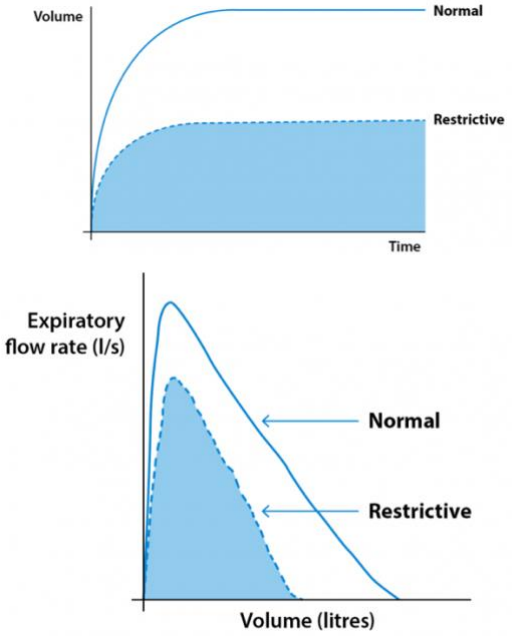
Obstructive Lung Disease





Note: Reduction in peak-expiratory flow rate; “scooped-out” appearance of expiratory tracing

Restrictive Lung Disease



Note: Reduction in lung volumes – FVC, TLC

Define COPD

Working definition

COPD should be considered in any patient who has dyspnea, chronic cough or sputum production, and/or a history of exposure to risk factors for the disease. Spirometry is required to establish the diagnosis in this clinical context; the presence of a post-bronchodilator FEV1/FVC < 0.70 confirms the presence of persistent airflow limitation and thus of COPD in patients with appropriate symptoms and significant exposures to noxious stimuli.

The key indicators are:

Dyspnoea that is:

Progressive over time;
Characteristically worse with exercise;
Persistent.

Chronic cough:

May be intermittent and may be unproductive,
Recurrent wheeze.

Chronic sputum production:

Any pattern of sputum production may indicate COPD.

Recurrent lower respiratory tract infections

History of risk factors:

Host factors (such as genetic factors, congenital/developmental abnormalities etc),
Tobacco smoke (including popular local preparations).
Smoke from home cooking and heating fuels.
Occupational dusts, fumes, gases and other chemicals.

Family history of COPD and/or Childhood factors:

For example low birth weight, childhood respiratory infections etc.

According to American Thoracic Society, COPD is a disease state characterized by the presence of airflow obstruction due to chronic bronchitis or emphysema; the airflow obstruction is generally progressive, may be accompanied by airway hyperreactivity, and may be partially reversible.

Define exacerbation of COPD

COPD exacerbation is defined as an event in the natural history of the disease characterized by a change in the patient's baseline dyspnea, cough and/or sputum that is beyond normal day-to-day variations, is acute in onset, and may warrant a change in regular medication in a patient with underlying COPD. During exacerbations there is increased hyperinflation and gas trapping, with reduced expiratory flow, thus accounting for the increased dyspnoea. There is also worsening of V/Q abnormalities (ventilation- perfusing mismatch), which can result in hypoxemia.

Comment on reversibility of small airway obstruction on PFTs?

Patients showing small airway obstruction on PFT should be tested twice—once before bronchodilators, and then after administration of bronchodilators to evaluate the responsiveness to a bronchodilator medication. The drug almost always used is a β-2 selective sympathomimetic because it causes bronchodilation but which does not stimulate the heart to any great degree. If two out of three measurements (FVC, FEV1 and FEF25%–75%) improve, then it can be said that the patient has a reversible airway obstruction that is responsive to medication.

1. FVC: An increase of 10% or more
2. FEV1: An increase of 200 mL or 15% of the baseline FEV1
3. FEF25%-75%: an increase of 20% or more.

In patients with airway obstruction, absence of a response to a single exposure to a bronchodilator, however, does not preclude a beneficial response to maintenance therapy and many clinicians prefer to use bronchodilators even in the absence of above mentioned criteria.

Explain the methods of measuring residual lung volume?

1. Gas dilution techniques use either closed-circuit helium dilution or open-circuit nitrogen washout.

– Nitrogen washout technique—In this technique, at the end of a normal expiration, the patient breathes 100% oxygen and all the nitrogen in the lung is "washed out." The exhaled volume and the nitrogen concentration in that volume are measured. The difference in nitrogen volume at the initial concentration and at the final exhaled concentration allows a calculation of intrathoracic volume, usually FRC.

– Helium dilution technique—It is based on the inhalation of a known concentration and volume of an inert tracer gas, such as helium, followed by equilibration of 7 to 10 minutes in the closed-circuit. The final exhaled helium concentration is diluted in proportion to the unknown volume of air in the patient's chest (RV). Usually, the

patient is connected at the end-tidal position of the spirometer; therefore, the lung volume measured is FRC.

2. Body plethysmography—It is based on the principle of Boyle's law, which states that the volume of gas at a constant temperature varies inversely with the pressure applied to it. In this technique, the patient sits in a closed "body box" with a known volume and the lung volumes are calculated based on the amount of air displaced from the box during ventilation.

Explain Diffusion Lung Carbon Monoxide (DLCO)

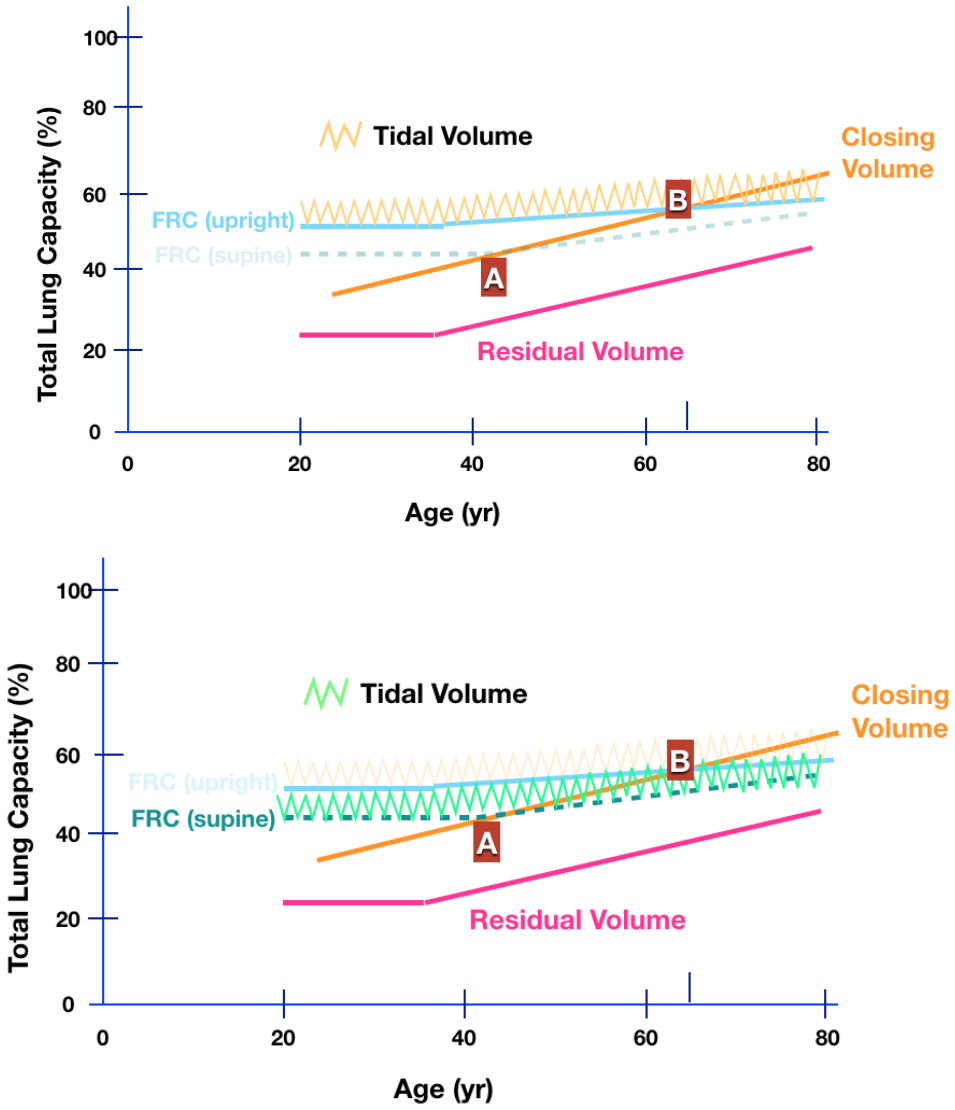
DLCO is a measurement of the ease of transfer for CO molecules from alveolar gas to the hemoglobin of the red blood cells in the pulmonary circulation. It is also called the transfer factor of carbon monoxide (TLCO mmol/ min/kilopascal), which describes the process more accurately. DLCO is a measure of the interaction of alveolar surface area, alveolar capillary perfusion, the physical properties of the alveolar capillary interface, capillary volume, hemoglobin concentration, and the reaction rate of carbon monoxide and hemoglobin.

The most commonly used and standardized technique to measure DLCO is the single-breath technique. In this technique, a subject inhales a known volume of test gas that contains 10% helium, 0.3% carbon monoxide, 21% oxygen, and the remainder nitrogen. The patient inhales the test gas and holds breath for 10 seconds. The patient exhales to wash out a conservative overestimate of mechanical and anatomic dead space. Subsequently, an alveolar sample is collected. DLCO is calculated from the total volume of the lung, breath-holding time and the initial and final alveolar concentrations of carbon monoxide. The exhaled helium concentration is used to calculate a single-breath estimate of total lung capacity and the initial alveolar concentration of carbon monoxide.

Effects of positioning and anesthesia on FRC- functional residual capacity

Anaesthesia leads to fall in FRC despite maintaining spontaneous breathing and irrespective of anaesthetic used (intravenous [IV] or inhalational).[4,5] FRC (approximately 3L in normal person) falls by 0.8–1.0 L by a change in position from upright to supine due to upward pressure from abdominal contents and more cephalad position of the diaphragm. Induction of GA further decreases it by 0.4–0.5 L due to relaxation of diaphragm and intercostal muscles, which further moves the diaphragm up. The resultant volume is close to residual volume. The muscle paralysis and mechanical ventilation does not cause any further reduction in FRC. As FRC approaches closing capacity, small airways collapse resulting in atelectasis and consequently hypoxia. Atelectasis occurs in approximately 90% of the patients undergoing anaesthesia. FRC increases significantly in the 30° head-up position in comparison with supine. PEEP applied during anaesthesia may increase FRC; however, patients with high intra-abdominal pressure (IAP) may require PEEP higher than IAP.

FRC is also reduced in neonates, elderly, obesity, smokers, pregnancy, abdominal distension and patients with respiratory diseases even before induction of anaesthesia. Total static compliance (both lung and chest walls) is also reduced, which may be due to decrease in FRC. FRC remains unaffected during ketamine anaesthesia as muscle tone is maintained.



Lung volumes and aging: Residual volume and functional residual capacity (FRC) increase with aging while total lung capacity does not change. The closing volume increases with aging and exceeds FRC around age 65 in the upright position (B). However, because FRC is lower in supine body position, closing volume exceeds FRC at age 45 while supine (A).

PRACTICE PROBLEMS - PFT INTERPRETATION

Continuing from the 4 practice problems discussed in the video
https://youtu.be/nwoRjRfuJjs

Practice Problem – 5
60-year old male with history of tobacco chewing and cigarette smoking for 40 years. He is diagnosed with carcinoma of gallbladder and is being planned for radical cholecystectomy.

Spirometry	Predicted	Pre-bronchodilator actual	Pre-bronchodilator % Predicted	Post-bronchodilator actual	Post-bronchodilator % Predicted	Post-bronchodilator % change
FVC	3.37	2.5	74	2.77	82	11
FEV1	2.69	1.33	49	1.89	70	42
FEV1/FVC	76	53	70	68	90	28
FEF 25-75%	3.24	0.58	18	1.47	45	153
MVV	118	42	35	57	48	37

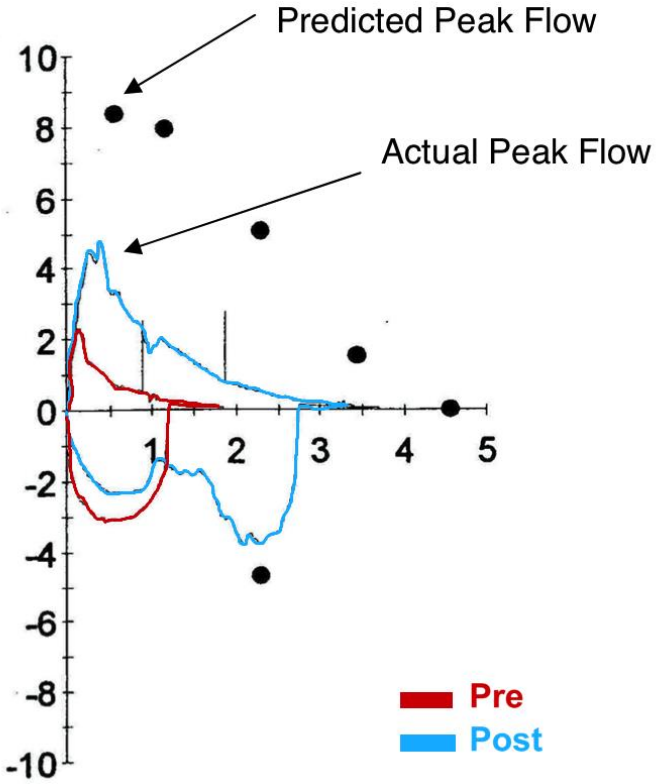
Key:
FEV1/FVC - 70% (decreased).
FVC, FEV1, and FEF 25%–75% are all reduced.
MVV is decreased as well.
This is suggestive of an obstructive pattern.
Significant reversibility is noted post-bronchodilator administration.

Practice Problem – 6

A 54 year-old man presents to his primary care provider with dyspnea and a cough. He is a non-smoker with no relevant occupational exposures.

	Pre-Bronchodilator (BD)			Post- BD	
Test	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	3.19	4.22	76	4.00	25
FEV_1 (L)	2.18	3.39	64	2.83	30
FEV_1/FVC (%)	68	80		71	4

His flow-volume loop is as follows:



Key:

FEV1/FVC ratio – decreased

FVC – decreased

Consistent with diagnosis of air-flow obstruction (“moderate).

Reversibility: FVC improves by 0.81 L (25% increase) and the FEV1 improves by 0.65L (30% increase) following administration of a bronchodilator.

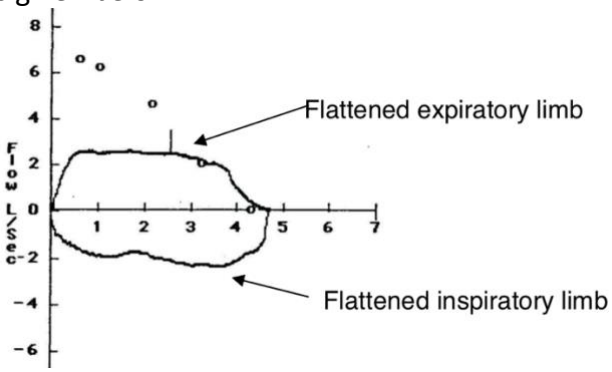
The flow volume loop shows: (i) peak expiratory flow rate is lower than the predicted peak expiratory flow and (ii) the curve has the characteristic “scooped out appearance” typically seen in airflow obstruction.

Practice Problem – 7

A 25 year-old man presents to his physician with complaints of dyspnea and wheezing. He is a non-smoker. Two years ago, he was in a major motor vehicle accident and was hospitalized for 3 months. He had a tracheostomy placed because he remained on the ventilator for a total of 7 weeks. His tracheostomy was removed 2 months after his discharge from the hospital. His pulmonary tests are as follows:

	Pre-Bronchodilator (BD)		
Test	**Actual**	**Predicted**	**% Predicted**
FVC (L)	4.73	4.35	109
FEV_1 (L)	2.56	3.69	69
FEV_1/FVC (%)	54	85	

His flow-volume loop is given below:



Key:

FEV1/FVC is 54% - suggesting airflow obstruction

FVC is normal.

As per our flowchart – diagnosis of obstructive airway disease

Note that there is flattening of both the inspiratory and expiratory limbs in the flow-volume loop. This pattern is seen in patients who have a fixed upper airway obstruction. In a patient with a prior history of tracheostomy, you would be very suspicious that this patient has developed tracheal stenosis, a known long-term complication of tracheostomy tubes.

Practice Problem – 8

A 41 year-old woman presents to the pulmonologist complaining of dyspnea with mild exertion. She has a 10 pack-year history of smoking and a history of using intravenous drugs including heroin and ritalin. Her pulmonary function tests are as follows:

	Pre-Bronchodilator (BD)			Post- BD	
Test	**Actual**	**Predicted**	**% Predicted**	**Actual**	**% Change**
FVC (L)	0.90	3.09	29	0.74	- 17
FEV_1 (L)	0.49	2.57	19	0.44	-10
FEV_1/FVC (%)	54	83		59	8
RV (L)	3.83	1.49	257		
TLC (L)	4.78	4.44	108		
RV/TLC (%)	80	33			
DLCO corr	0.75	24.85	3		

Key:

FEV1/FVC is decreased.

FVC is decreased; TLC is normal.

Suggestive of Obstructive lung disease.

DLCO is decreased markedly, indicating a loss of alveolar-capillary surface area for gas exchange.

/ Two disorders can present with early-onset emphysema with a basilar predominance: alpha-one anti-trypsin deficiency (it is usually only seen this early if the person also smokes) and ritalin lung. The latter is an uncommon form of the severe basilar-predominant emphysema seen in people who previously used intravenous injections of ritalin (methylphenidate)./

Practice Problem – 9

A 30 year-old woman presents for evaluation of dyspnea on exertion, which has been present for more than one year. She is a life-long non-smoker with no prior history of asthma or other pulmonary problems. She works as a receptionist at a corporate hospital. She has two cats and several parakeets at home. Her pulmonary function testing is as follows:

	Pre-Bronchodilator (BD)			Post- BD	
Test	**Actual**	**Predicted**	**% Predicted**	**Actual**	**% Change**
FVC (L)	1.73	4.37	40	1.79	4
FEV_1 (L)	1.57	3.65	43	1.58	0
FEV_1/FVC (%)	91	84		88	-3
RV (L)	1.01	1.98	51		
TLC (L)	2.68	6.12	44		
RV/TLC (%)	38	30			
DLCO corr	5.13	32.19	16		

Key:

FEV1/FVC – normal; indicates no airflow obstruction

FVC, TLC – grossly reduced; confirms that she has a restrictive process.

Based on her TLC of < 50% predicted, she would be classified as having a “severe” restrictive defect.

Her DLCO is also reduced suggesting she has a loss of alveolar-capillary surface area for gas exchange and also suggesting that the cause of her restriction is intrinsic to the lungs (i.e. due to a problem in the pulmonary parenchyma).

Practice Problem – 10

A 64 year-old woman presents with complaints of dyspnea and orthopnea. She is a life-long non-smoker. Her pulmonary function testing is as follows:

	Pre-Bronchodilator (BD)			Post- BD	
Test	**Actual**	**Predicted**	**% Predicted**	**Actual**	**% Change**
FVC (L)	1.00	2.51	40	1.02	3
FEV_1 (L)	0.61	2.00	30	0.69	13
FEV_1/FVC (%)	61	80		67	10
RV (L)	1.15	1.55	74		
TLC (L)	2.08	4.04	52		
RV/TLC (%)	55	39			

Key:

FEV1/FVC – reduced; suggesting airflow obstruction

FVC, TLC reduced; This is evidence of a restrictive defect and, therefore, this patient would be labeled as having a combined obstructive- restrictive defect.

A DLCO is not provided which makes it difficult to determine if the cause of her restriction is due to a pulmonary parenchymal process or an extra-pulmonary process.