Practical for respiratory system

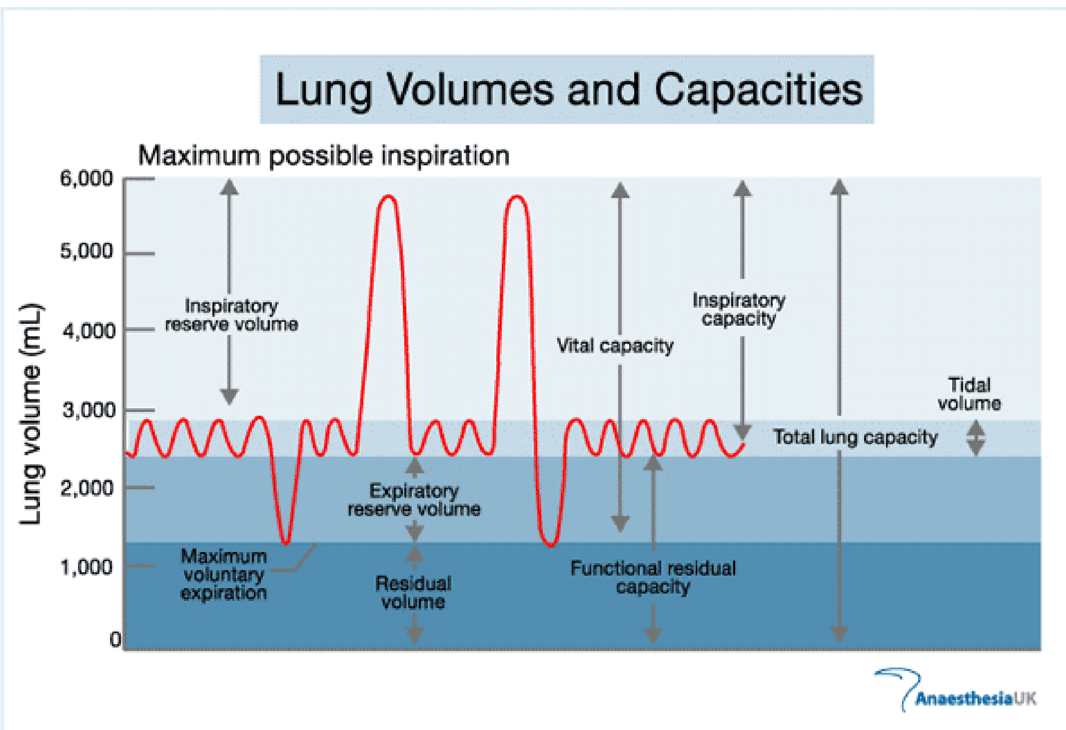
When talking about pulmonary ventilation we can "group" the air traveling through the lungs into four lung volumes and four capacities.

Lung volumes (that are not overlapping):

a. Tidal Volume (TV): the amount of air we breathe in and out during a normal breath, which is approximately 500 ml.
b. Inspiratory Reserve Volume (IRV): the amount we can breathe in over and above tidal volume, or about 3000 ml.
c. Expiratory Reserve Volume (ERV): This is the amount we can breathe out beyond normal exhalation (that is, the end of a normal tidal volume breath), which is about 1200 ml.
d. Residual Volume (RV): the amount of air that is left in the lung even after a forced exhalation approximately 1200 ml

Lung capacities represent combinations of volumes.

a. Inspiratory Capacity (IC): TV + IRV
b. Vital Capacity (VC): IRV + TV +ERV (or IC + ERV): This is the maximum amount of air that can be expelled from the lungs after first taking in as much air as you can. (aprox 4600 ml)
c. Total Lung Capacity: VC + RV: The total volume that the lung can contain after a maximum inspiration (aprox. 6000 ml)
d. Functional Residual Capacity (FRC): ERV plus RV: The amount left in the lungs after normal expiration. This is about 2300 ml.



Measuring lung volumes:

A. To measure the vital capacity and its subcomponents we can use a spirometer.

B. Residual Volume. cannot be measured directly by spirometry . In practice the technique is to measure FRC, and then RV is determined by subtracting expiratory reserve volume.

C. Forced vital capacity (FVC) - the volume of air that can be maximally forcefully exhaled.

D. Forced expiratory volume 1 (FEV1) - the volume of air that is forcefully exhaled in one second. Ratio of FEV1 to FVC (FEV1/FVC) - expressed as a percentage. Normal FEV/FVC ~ 80%.

E. Forced expiratory flow (FEF25 - 75) - the average forced expiratory flow during the mid (25 - 75%) portion of the FVC.

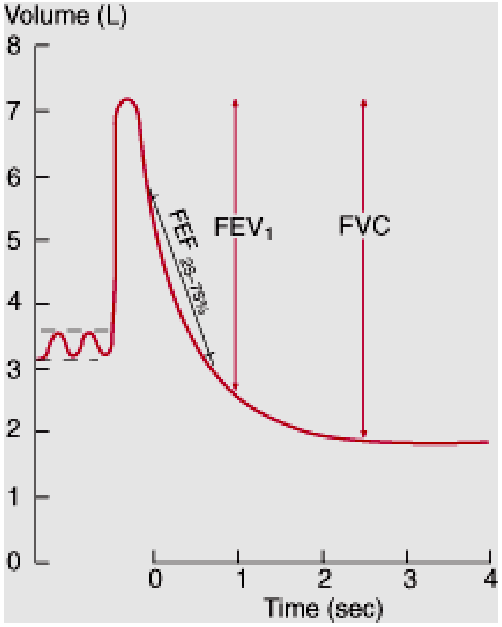
F. Peak expiratory flow rate (PEFR) - the peak flow rate during expiration

Spirometry is typically reported in both absolute values and as a predicted percentage of normal. Normal values vary, depending on gender, race, age and height. It is therefore not possible to interpret pulmonary function tests (PFTs) without such information.

Flow rates: Quantitative measures of inspiratory and expiratory flow are obtained by forced spirometry. Nose clips are used to occlude flow of air through the nose.

In assessments of expiratory flow, the patient inhales as deeply as possible, seals his lips around a mouthpiece, and exhales as forcefully and completely as possible into an apparatus that records the exhaled volume (forced vital capacity [FVC]) and the volume exhaled in the first second (the forced expiratory volume in 1 sec [FEV1]. Flow-volume loops, in contrast to the spirogram, which displays flow (in L) over time (in sec), the flow-volume loop displays flow (in L/sec) as it relates to lung volume (in L) during maximal inspiration from complete exhalation (residual volume [RV]) and during maximum expiration from complete inhalation (TLC). The principal advantage of the flow-volume loop is that it can show whether flows are appropriate for a particular lung volume. For example, flow is normally slower at low lung volumes. Because patients with pulmonary fibrosis have low lung volumes, flow appears to be decreased if measured alone. However, when flow is measured against lung volumes, it becomes apparent that flow is actually higher than normal because of the increased elastic recoil characteristic of fibrotic lungs.

Flow rate and lung volume measurements can be used to differentiate obstructive from restrictive pulmonary disorders, to characterize disease severity, and to measure responses to therapy.



FEV$_1$ = forced expiratory volume in the 1st second of forced vital capacity manoeuvre; FEF$_{25–75\%}$ = forced expiratory flow during expiration of 25 to 75% of the FVC; FVC = forced vital capacity (the maximum amount of air forcibly expired after maximum inspiration).

Characteristic Physiologic Changes Associated With Pulmonary Disorders

Measure	Obstructive Disorders	Restrictive Disorders	Mixed Disorders
FEV$_1$/FVC	Decreased	Normal or increased	Decreased
FEV$_1$	Decreased	Decreased, normal, or increased	Decreased
FVC	Decreased or normal	Decreased	Decreased
TLC	Normal or increased	Decreased	Decreased
RV	Normal or increased	Decreased	Decreased, normal, or increased

FEV$_1$ = forced expiratory volume in 1 sec; FVC = forced vital capacity;
TLC = total lung capacity; RV = residual volume.

Obstructive disease is a reduction in flow rates, particularly the FEV$_1$ and the FEV$_1$ as a percentage of the FVC (FEV$_1$/FVC). The reduction in FEV$_1$ determines the degree of the obstructive defect. Obstructive defects are caused by increased resistance to flow from abnormalities within the airway lumen (eg, tumors, secretions, mucosal thickening); changes in the wall of the airway (eg, contraction of smooth muscle, edema); or elastic recoil (eg, the parenchymal destruction that occurs in emphysema). With decreased flow rates, expiratory times are longer than usual, and air may become trapped in the lungs from incomplete emptying and increased lung volumes (eg, TLC, RV).

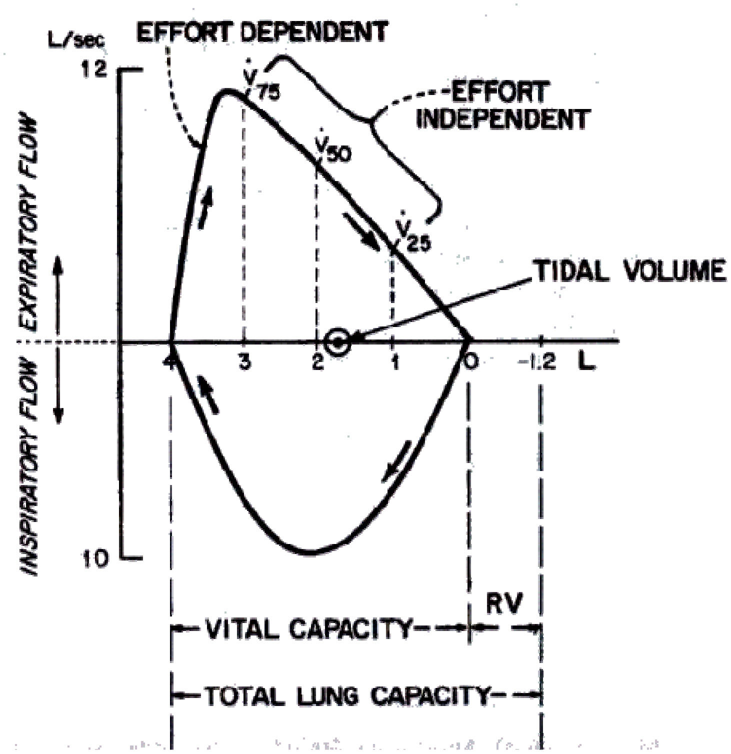
Restrictive disease is a reduction in lung volume, specifically, a TLC < 80% of the predicted value. The decrease in TLC determines the severity of restriction. The decrease in lung volumes produces a decrease in flow rates (reduced FEV$_1$ and FVC. However, the airflow relative to the specific volume is increased, so the FEV$_1$/FVC ratio is normal or increased. Restrictive defects are caused by a loss in lung volume (eg, lobectomy), abnormalities of structures surrounding the lung (eg, pleural disease, kyphosis, obesity), weakness of the inspiratory muscles of respiration (eg, neuromuscular disease), or abnormalities of the lung parenchyma (eg, pulmonary fibrosis). The feature common to all is a decrease in the compliance of the lungs, the chest wall, or both.

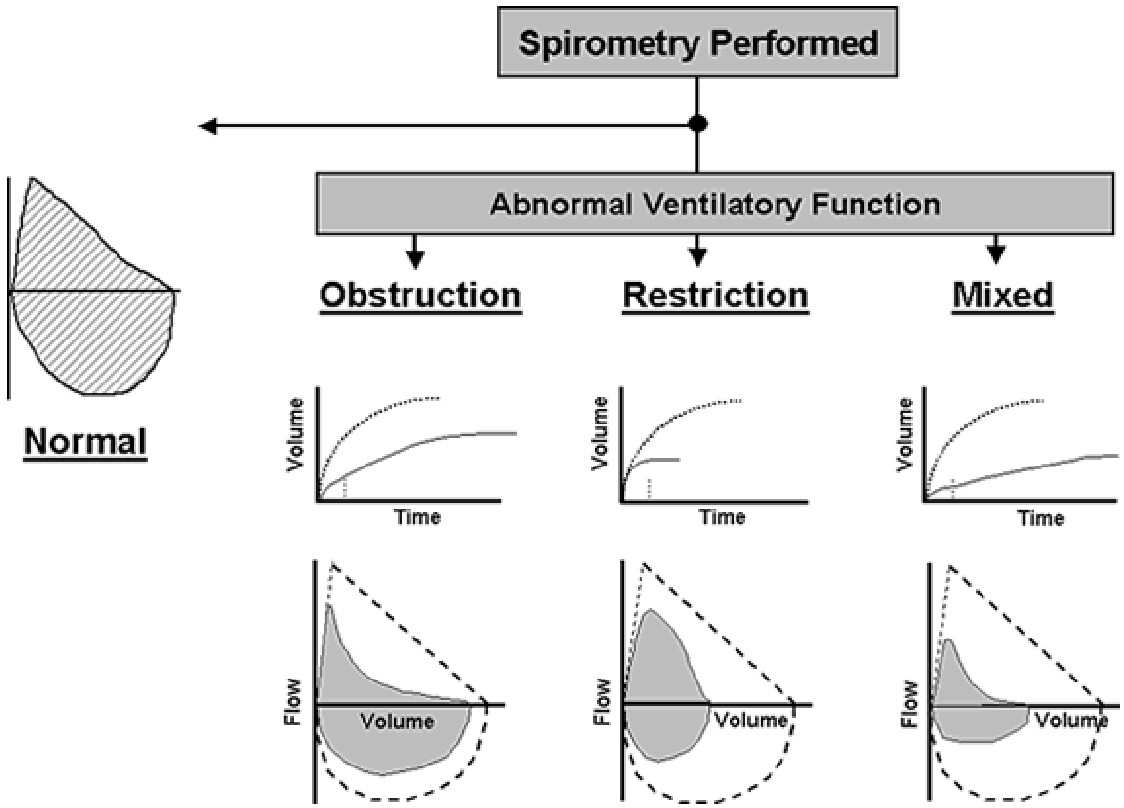
Severity of Obstructive and Restrictive Lung Diseases

Severity*	Obstructive FEV_1/FVC (% predicted)	FEV_1 (% predicted)	Restrictive TLC (% Predicted)
Normal	≥ 70	≥ 80	≥ 80
Mild	< 70	≥ 80	70–79
Moderate	< 70	$50 \leq FEV_1 < 80$	50–69
Severe	< 70	$30 \leq FEV_1 < 50$	< 50
Very severe	< 70	< 30 or < 50 with chronic respiratory failure	—

Flow-volume Loop

Flow volume loops characterize airflows as a function of volumes (flows and flow volume are plotted concurrently).
The process is initiated by inspiration to total lung capacity followed by a forced vital capacity activity. Maximal, rapid, inhalation is then performed back to total lung capacity. The effort dependent part of the loop includes the entire inspiratory components and the expiratory part of the curve near the total lung capacity.
By contrast, the expiratory flow from about 25% to about 75% of the vital capacity is effort independent. Usually the ratio of expiratory flow to inspiratory flow at 50% of vital capacity (mid-VC flow ratio) approximates 1. This ratio is useful in the identification of upper airway obstruction.
Patients with pulmonary fibrosis or scoliosis (restricted defects), exhibit a reduced FVC while retaining a comparatively normal FEV_1.
Total lung capacity will be reduced while $FEF_{25\%-75\%}$ and mid-VC flow ratio remains normal.
In patients with obstructive lung defect, peak expiratory flow rate, $FEF_{25\%-75\%}$ and mid-VC flow ratios will be reduced although total lung capacity (TLC) will be increased due to increases in RV.





Flow Volume Loops in Normal subjects and subjects with obstructive and restrictive defects