DYNAMIC SPIROMETRY

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What is Spirometry ?

- It is a measurement of the breathing capacity of the lungs.
- It is the most basic and frequently performed test of pulmonary (lung) function.

Why "Dynamic" ?

It measures the *rate* at which the lung changes volumes during forced breathing maneuvers.

How is it performed?
Requirements

- Vitalograph.
- Mouthpiece (disposable).
- Nose clip.

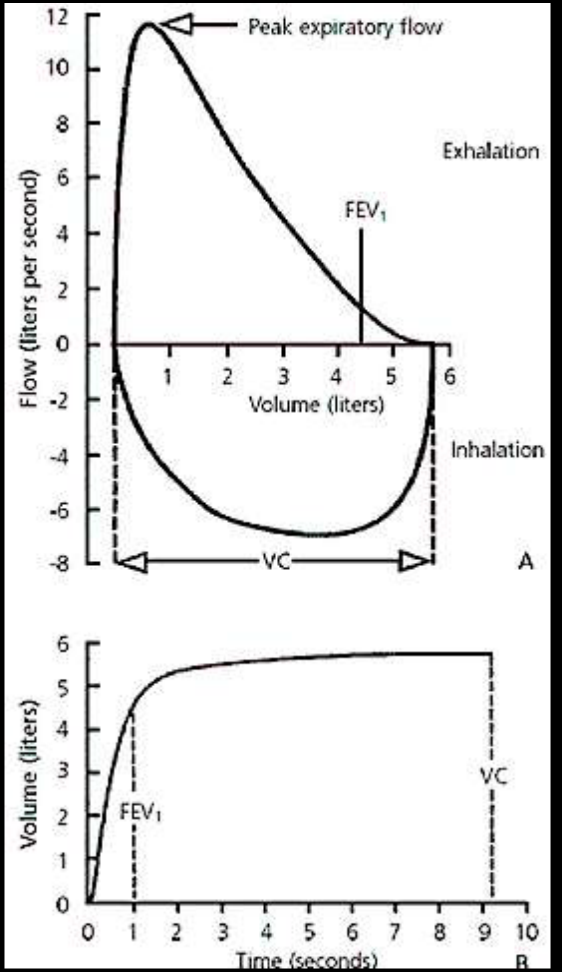
Procedure

- ✓ Make a tight seal around the mouthpiece.
- ✓ Ask subject to inhale deeply.
- ✓ Then ask the subject to exhale as strongly and as forcefully as possible and for as long as possible

Two types of curves can be obtained:

i. **Flow-volume curve (Loops).**

ii. **Forced expiratory volume curve (FEV).**



Forced Expiratory Volume Curve

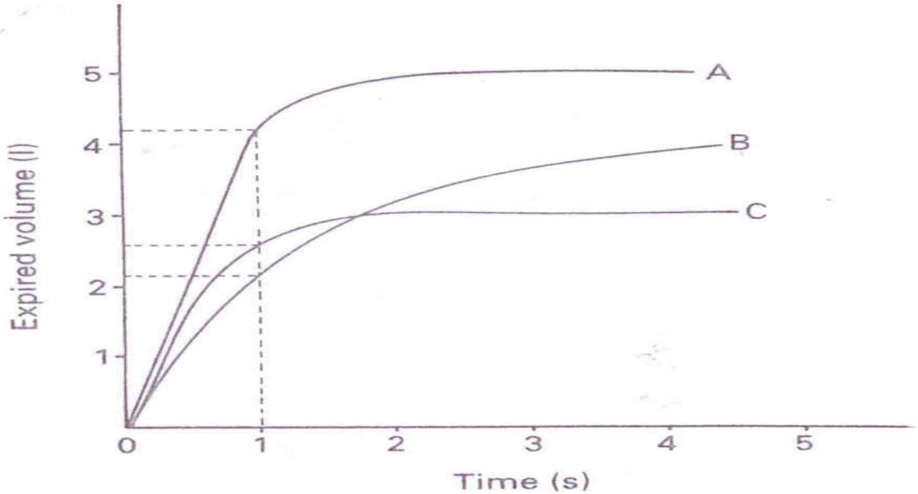


Fig. 6.24 Spirograms recorded by a 'vitalograph' for three patients. The maximum volume expired is the FVC for each patient. A: FVC = 5 litres; FEV_1 = 4.2 litres; FEV_1 = 84%—normal; B: FVC = 4 litres; FEV_1 = 2.2 litres; FEV_1 = 55%—obstructive lung disease; C: FVC = 3 litres; FEV_1 = 2.7 litres; FEV_1 = 90%—restrictive lung disease.

FEV1-FVC NORMAL VALUES

Parameter	Normal value (ATS/ERS)
FEV_1	≥ 70% (% predicted FEV1)
FVC	≥ 70% (% predicted FVC)
FEV_1/FVC ratio	≥ 70% (0.7)

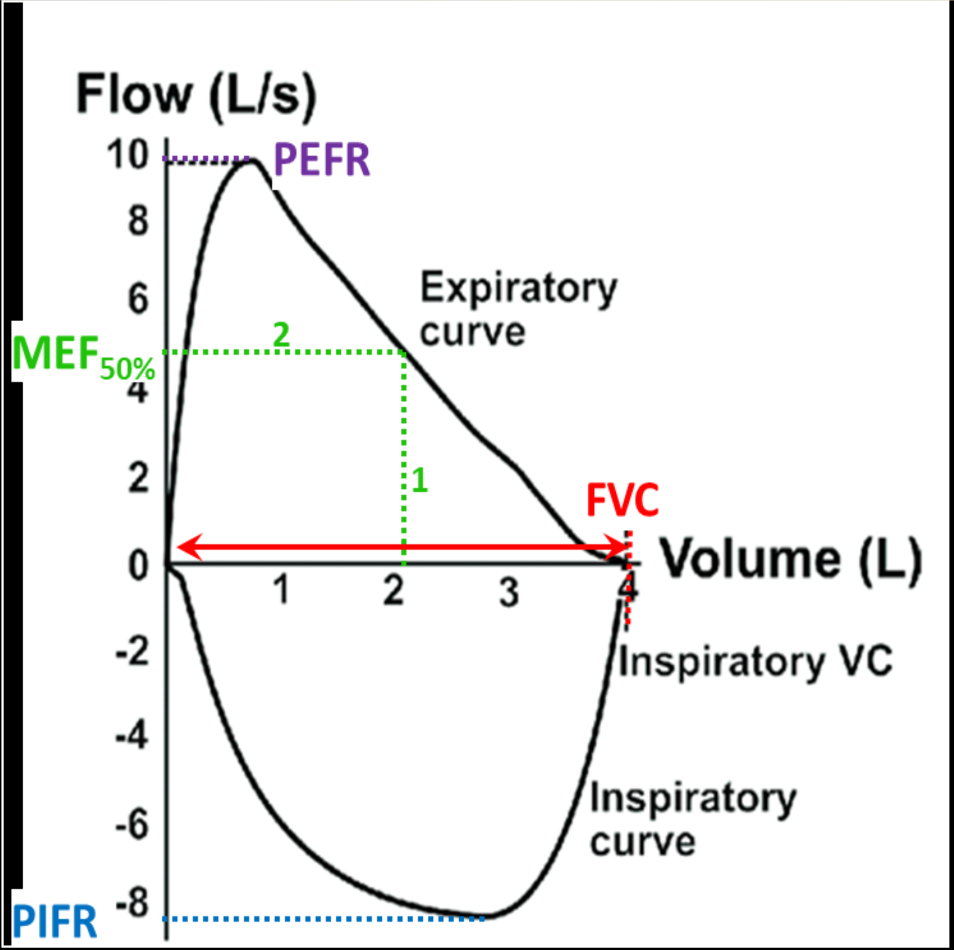
ATS=American Thoracic Society,
ERS=European Respiratory Society

Normally:

Forced expiratory curve Measures:

- **FEV1 = the volume of air exhaled in the 1st second.**
- **FVC = the total volume of exhaled air.**
- **FEV1/FVC ratio = normally ≈ 70% of predicted**

FLOW VOLUME LOOPS



Flow Volume Curve

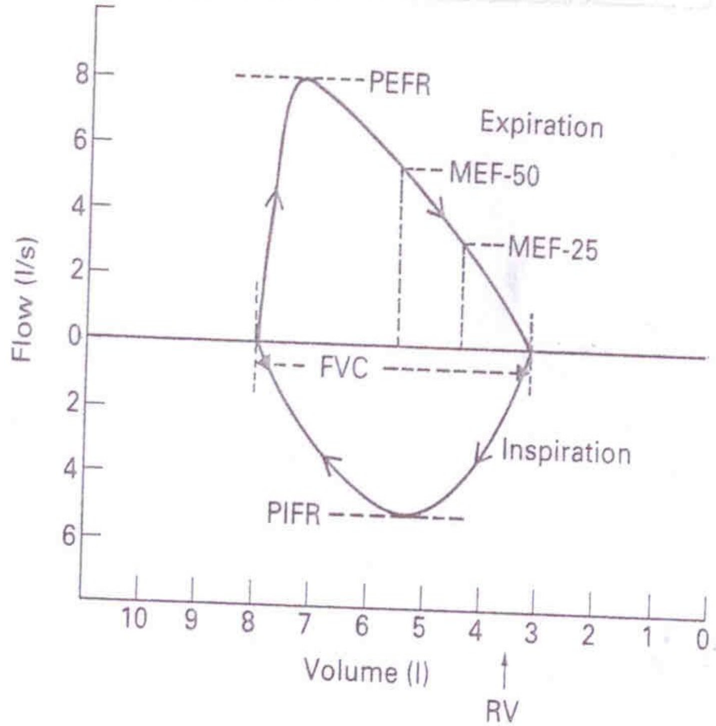


Fig. 6.27 Flow–volume loop in a normal subject. FVC, forced vital capacity; PIFR, peak inspiratory flow rate; PEFR, peak expiratory flow rate; MEF50, maximum expiratory flow at 50%

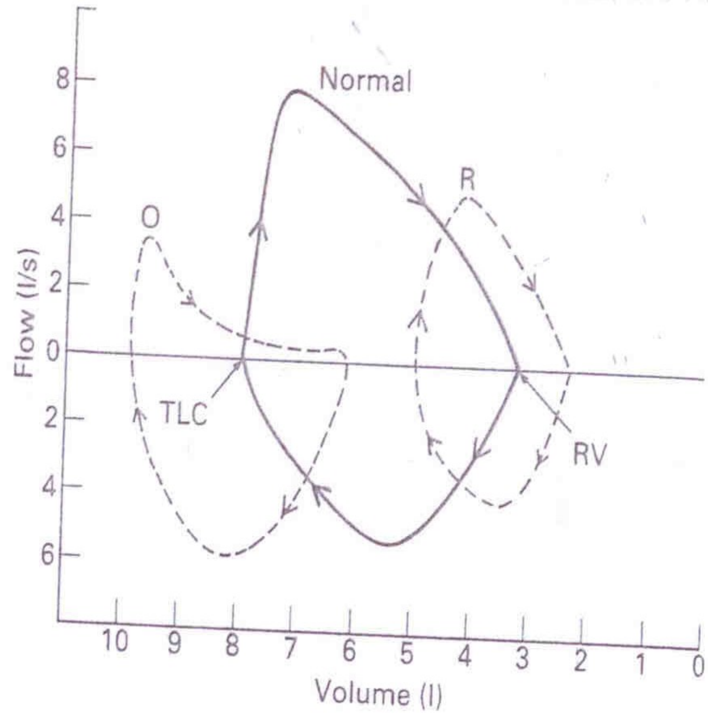


Fig. 6.28 Flow–volume loops in restrictive lung disease (R) and obstructive lung disease (O), compared with a normal subject. TLC, total lung capacity; RV, residual volume.

What is the importance of Spirometry?

- **Helps in the diagnosis of pulmonary diseases.**
- **Follow disease progression.**
- **Determine strength and function of the chest.**

Respiratory Diseases

Chronic Obstructive Pulmonary Diseases (COPD)

(↑ Airway resistance)
E.g. Role of Allergens and Bronchoconstriction

Chronic Restrictive Pulmonary Diseases (CRPD)

(↓ Lung compliance)
E.g. Role of Surfactant and external impedance or restriction to Flow

Obstructive Pulmonary Diseases
FINDINGS

- FEV1 ↓↓↓↓ in comparison to the predicted.
- FVC ↓ or ↔ in comparison to the predicted.
- FEV1/FVC ↓ in comparison to the predicted.

Eg:

COPD e.g. Emphysema
Or Bronchial Asthma

Restrictive Pulmonary Disease
FINDINGS

- FEV1 ↓↓ in comparison to the predicted.
- FVC ↓↓ in comparison to the predicted.
- FEV1/ FVC ↔ or ↑ in comparison to the predicted.

Eg:

Pulmonary fibrosis
Space occupying lesions and tumors

SPIROMETRY RESULTS

Parameter	Normal value (ATS/ERS)
FVC	≥ 70% (% predicted FVC)
FEV_1	≥ 70% (% predicted FEV1)
FEV_1/FVC ratio	≥ 70% (0.7)

COMPARATIVE FINDINGS

	Obstructive pattern	Restrictive pattern	Mixed pattern
FEV_1	↓↓↓	Normal or ↓	↓↓
FVC	Normal or ↓	↓↓↓	↓↓
FEV_1/FVC (FEV_1 %)	< 0.7 (70%)	Normal or > 0.7 (70%)	variable

Practice Questions

- Dynamic Spirometry was done on 3 patients, the results were the following:

A…. FEV1= 4L , FVC=5L
FEV1/FVC=80%

B…. FEV1=1.2L , FVC=3L
FEV1/FVC=40%

C…. FEV1= 2.7 L, FVC=3L
FEV1/FVC= 90%

Thank you

Practical 2. Dynamic Spirometry

2.1. Objectives

At the end of this session, students should be able to:

- Perform a dynamic spirometry test on a fellow student.
- Describe the two graphs recorded by dynamic spirometry, namely: flow-volume loop (FVL) and the volume-time curve (forced expiratory curve "FEV_1" curve).
- Analyze the components of each graph; FVL and FEV_1 and describe the characteristics of a normal FVL and FEV_1 graphs.
- Calculate the forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC) and the FEV_1/FVC ratio from the FEV_1 curve.
- Calculate the FVC, peak expiratory flow rate (PEFR), peak inspiratory flow rate (PIFR) and maximal expiratory flow rate at 50% of the forced vital capacity (MEF_{50}).
- Discuss the indications of dynamic spirometry in clinical practice.
- State the normal values for FEV_1, FVC and the FEV_1/FVC ratio.
- State the normal values of FVC, PEFR, PIFR and MEF_{50} in FVL.
- Describe the expected changes in FVL and FEV_1 curve in obstructive vs restrictive lung disease conditions.
- Describe the expected changes in FEV_1, FVC and the FEV_1/FVC ratio in obstructive vs restrictive lung disease conditions.
- Describe the expected changes in FVC, PEFR, PIFR and MEF_{50} in obstructive vs restrictive lung disease conditions.

2.2. Equipment

- Dynamic spirometer, Fig-10.
- Nose clip.
- Disposable mouth piece.

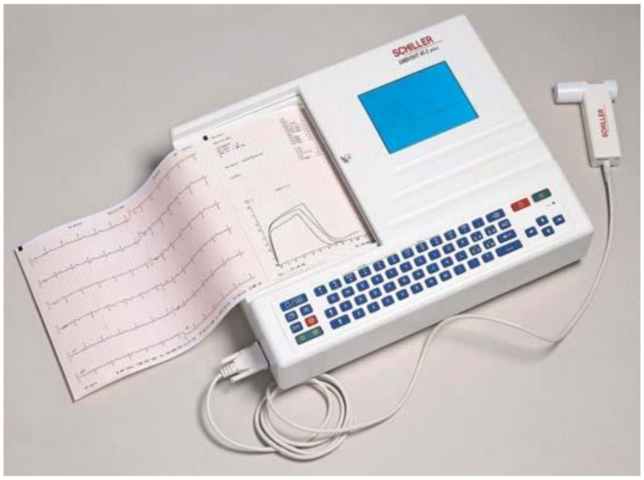


Figure 10. Automated spirometer.

2.3. Procedure

1. Insert a new disposable mouthpiece into the flow sensor (SP-250).
2. Hold the sensor in an upright position.
3. Insert the mouthpiece in the oral cavity (mouth) and seal the lips tightly around the mouthpiece.
4. Place the nose clip on the subject’s nose to avoid air escaping through nostrils.
5. While subject is standing, allow him/her to breathe normally through mouthpiece, approximately 3 normal breaths to record TV.
6. Then ask the subject to inhale as deep as possible and then follow it with a fast and forceful expiration. The expiration should be as fast and forceful as possible and it should continue until the subject is unable to blow out anymore.
7. Two types of graphs may be recorded, Fig-11.

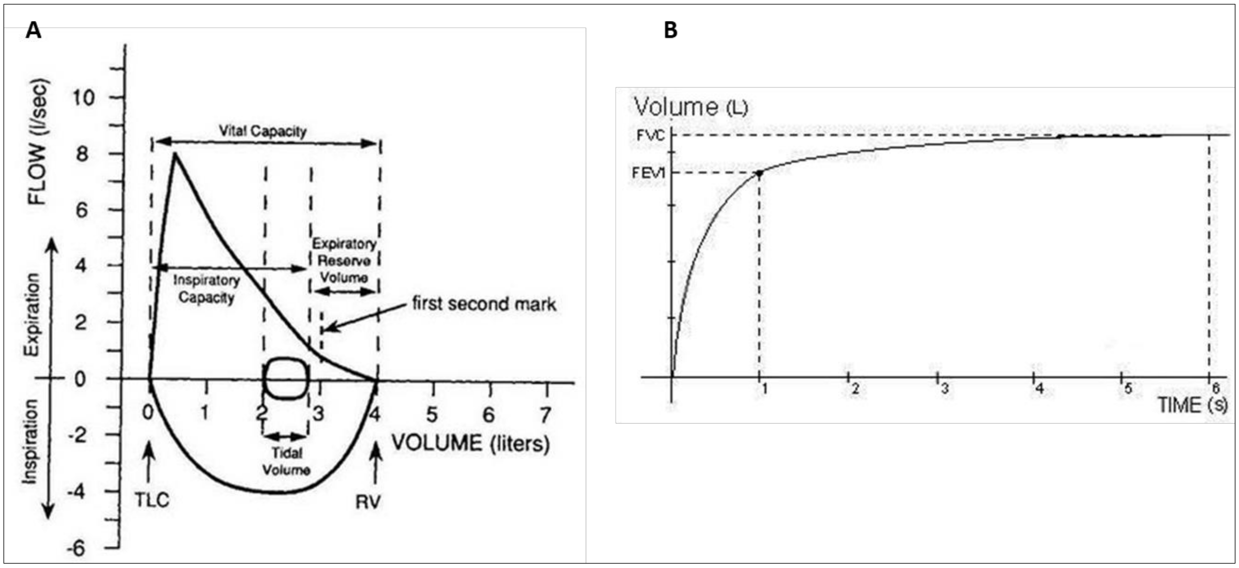


Figure 11. Dynamic spirometry graphs. (A) Flow-volume loop, (B) FEV1 curve.

2.4. The Flow-volume loop (FVL)

The FVL depicts the relationship between flow and volume under maximal effort of inspiration and expiration. The shape of the loop depends on the mechanical properties of the lung and may help in the diagnosis of ventilatory dysfunction. Fig-12 shows a normal FVL. The normal expiratory portion of a well-performed flow-volume loop is characterized by a rapid increase to the peak flow rate, followed by a nearly linear decrease in flow as the subject exhales toward residual volume. While normally the inspiratory portion shows a symmetric, saddle-shaped curve (1). The parameters that each student need to be familiar with and able to extrapolate from the FVL are: the peak expiratory flow rate (PEFR), peak inspiratory flow rate (PIFR), forced vital capacity (FVC) and maximum expiratory flow at the half-way point in the forced expiratory maneuver ($MEF_{50\%}$)-Fig-12.

Fig-13 shows FVL in normal compared to obstructive and restrictive pulmonary disorders.

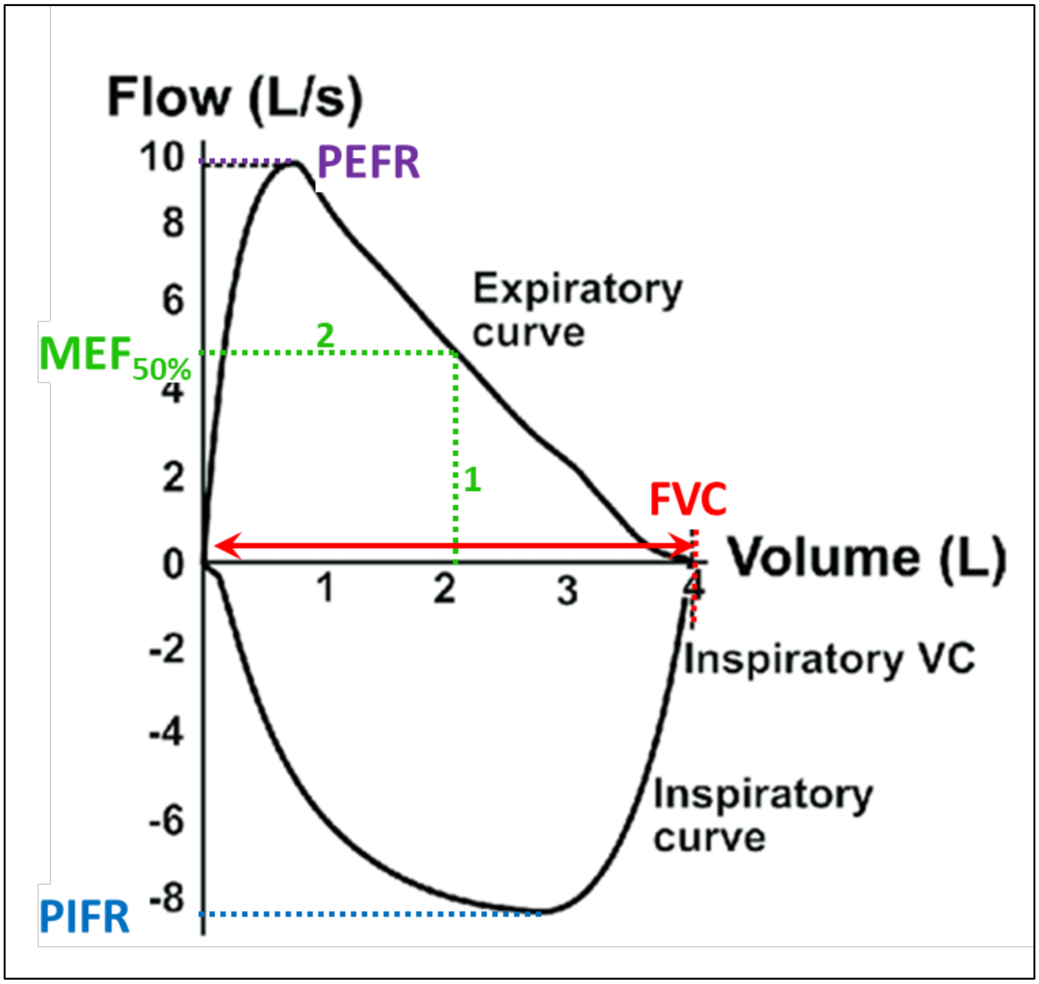


Figure 12. A normal flow-volume loop. The expiratory portion of the loop lies above the x-axis while the inspiratory potion of the loop lies below the x-axis. PEFR represents the maximal flow achieved during forced expiration while the PIFR represents the maximal flow achieved during inspiration. The FVC is the total expiratory volume from a maximally forced expiration maneuver. $MEF_{50\%}$ is determined from the graph by first establishing the point at which 50% of the vital capacity has been expired (i.e. 2L in the graph above). A line perpendicular to the x-axis (volume axis) is drawn from this point towards the expiratory curve (dotted line no. 1). At the point of intersection between dotted line no. 1 and the expiratory curve, another line is drawn (dotted line no. 2) perpendicular to dotted line no. 1 towards the y-axis (flow axis). The point of intersection of the y-axis with dotted line 2 represents the $MEF_{50\%}$.

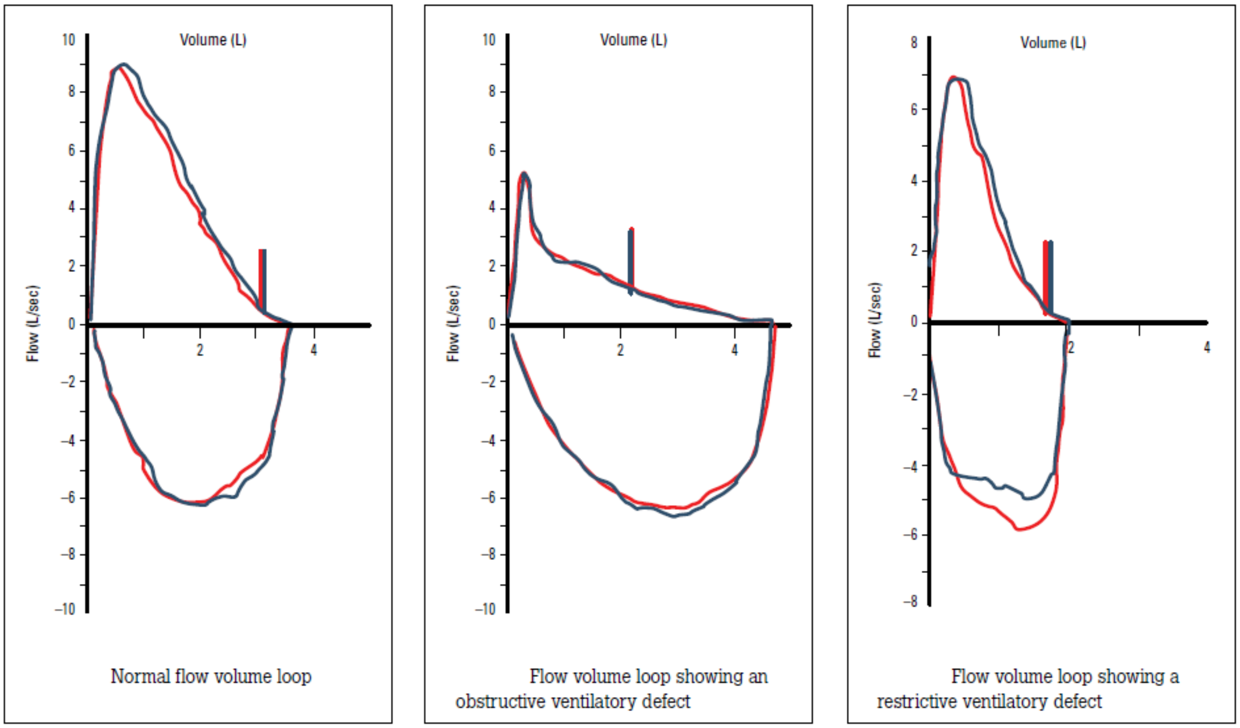


Figure 13. Shows a normal compared to FVLs of patients with obstructive and restrictive pulmonary disorders (reprinted from (2).

2.5. Volume-time graph (FEV_1 curve)

The volume-time graph or the FEV_1 curve depicts changes in volume (x-axis) against time (y-axis). Three main parameters are measured, namely, FVC, forced expiratory volume in the 1st second (FEV_1) and the ratio between these two numbers (FEV_1/FVC), Fig-14. When performing the test, one must ensure that the FEV_1 curve has reached a plateau and that expiration is maintained for at least 6 seconds (3, 4).

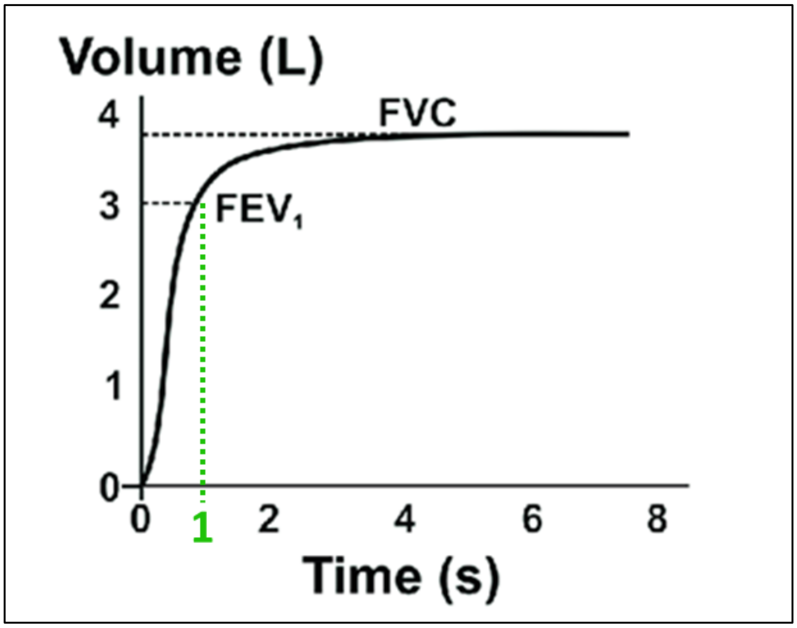


Figure 14. A normal volume-time graph (FEV_1 curve). The FVC represents the volume of air expired at the plateau. FEV_1 is the volume of air expired after 1 second of forced expiratory effort. Under normal conditions, more than 70% of the FVC is expired during the first second of expiration and this is what the ratio FEV_1/FVC reflects.

2.6. Normal values

Normal values are usually reported in 2 ways: as a volume measurement (ml or L of air), or as a percentage of the predicted normative or expected value for that patient's age, height, gender, and race from data obtained in the National Health and Nutrition Examination Survey III (NHANES III) (1).

Table 3. Normal FEV1 values (% predicted).

Parameter	Normal value (ATS/ERS)
FEV_1	≥ 70% (% predicted FEV1)
FVC	≥ 70% (% predicted FVC)
FEV_1/FVC ratio	≥ 70% (0.7)

ATS=American Thoracic Society,

ERS=European Respiratory Society

2.7. Diagnostic Differences between Obstructive and Restrictive Airway Diseases

Using spirometry, pulmonary disorders may be categorized into:

- Obstructive.
- Restrictive.
- Mixed.

Obstructive pulmonary disorders are characterized by expiratory airflow limitation and can be seen as a disproportionate reduction in FEV_1 as compared to FVC. While restrictive pulmonary disorders are characterized by a reduction in FVC. Table-2 shows the characteristic findings in FEV_1 curve in the different ventilatory defects.

Table 4. Pulmonary function test interpretation.

	Obstructive pattern	**Restrictive pattern**	**Mixed pattern**
FEV_1	↓↓↓	Normal or ↓	↓↓
FVC	Normal or ↓	↓↓↓	↓↓
FEV_1/FVC (FEV_1 %)	< 0.7 (70%)	Normal or > 0.7 (70%)	variable

2.8. Practice questions

1. From the FEV_1 curve produced in the lab, what is the value of the following:

Parameter	Value	
	Litres	% predicted
FEV_1		
FVC		
FEV_1/FVC ratio		

2. What is the expected normal value for FEV_1 in a normal person?

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3. How long does it take a healthy subject to expire approximately 70% of their vital capacity?

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4. Briefly explain what happens to FVC, FEV_1 and FEV_1 % measurements in patients with obstructive and restrictive lung diseases.

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5. From the flow volume loop recorded, what is the value of the following parameters:

Parameter	Value	
	Litres	**% predicted**
PEFR		
PIFR		
FVC		
$MEF_{50\%}$		

6. Briefly describe the important characteristics of the flow-volume curve recorded in a normal healthy person.

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7. Why is the force-independent part of the expiratory loop curvilinear in obstructive lung disease?

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8. What is the clinical significance of MEF50 measurements?

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2.9. Further resources

- Paraskeva et al. Spirometry. 2011. Australian Family Physician. 40 (4): 216-219.
- Johnson et al. A stepwise approach to the interpretation of pulmonary function tests. 2014. American Family Physician. 89 (5): 359-366.

2.10. Summary

Fig-15 summarizes the findings seen in FVL and FEV_1 curve in abnormal ventilatory conditions compared to normal.

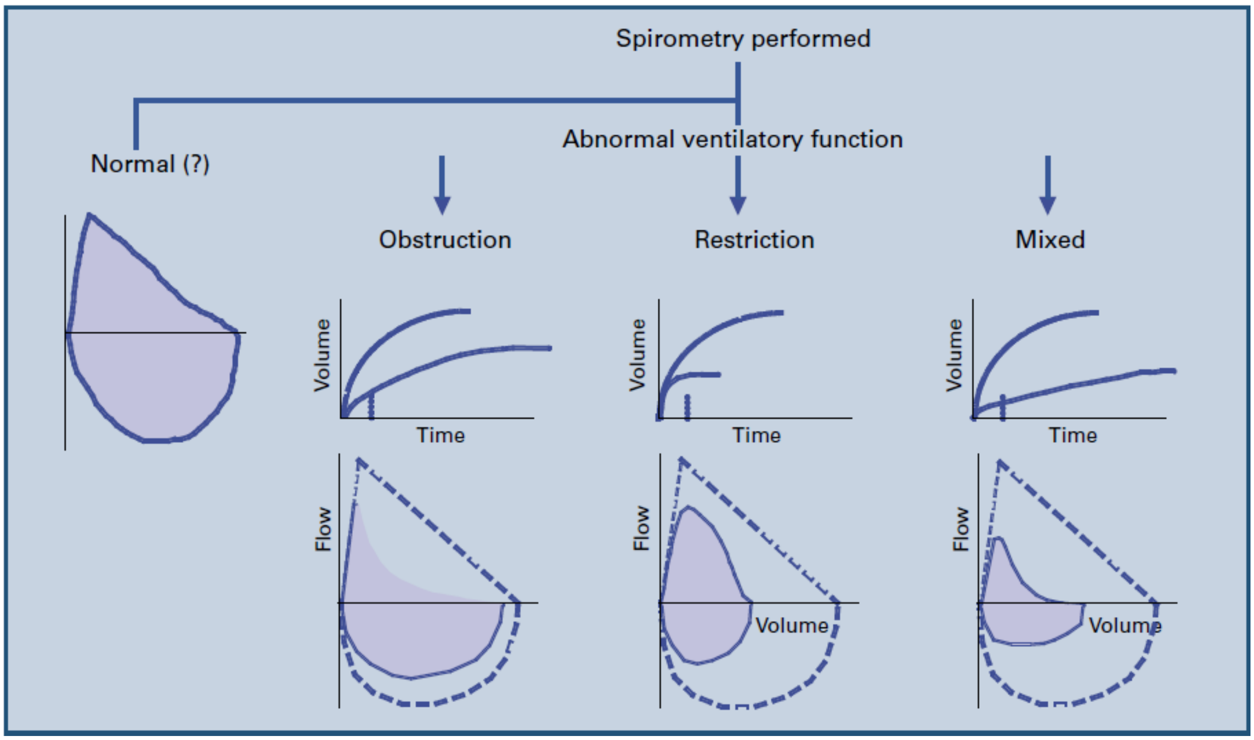

Figure 15. Typical spirograms and FVL in different ventilatory conditions (5).