Chapter 2: Respiratory Block Physiology Practical

There are 2 practical physiology sessions during the respiratory block which include;

1. Static spirometry (lung volumes & capacities).
2. Dynamic spirometry.

Spirometry is one of the essential pulmonary function tests performed in clinical practice. It is concerned with the measurement of flow and volume of air entering and leaving the lungs. Two major types of spirometry measurements are usually performed: simple and dynamic. Simple spirometry is used for the determination of lung volumes and capacities, whereas dynamic spirometry measures the flow of air moving in and out of the lungs. In the following sections you will be introduced to the procedures used for measuring both simple and dynamic spirometry, their indications and result interpretation.

Practical 1. Simple Spirometry (Lung Volumes and Capacities)

1.1. Objectives

At the end of this session, students are expected to:

1. Describe how a bell-type spirometer is used to measure lung volumes and capacities.
2. List and define the different lung volumes and capacities.
3. State the normal values of each lung volume and capacity.
4. Discuss the physiological and pathological factors that may affect the different lung volumes and capacities.

1.2. Equipment

1. Simple spirometer (many types are available, Bell-type spirometer or water-gauge spirometer), Fig-7. It would be best if students acquaint themselves with the type used in the lab.
2. Nose clip.
3. Disposable mouth piece.

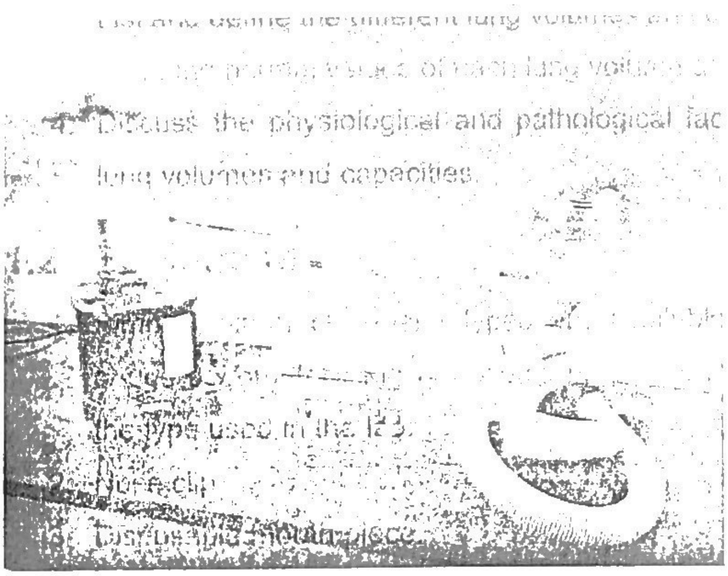


Figure 7. Simple (volumetric) spirometer.

1.3. Procedure

1. Insert the mouthpiece in the subject's mouth so that its edges lie between the subject's lips and gums.
2. Place the nose clip on the subject's nose to avoid air escaping through the nose.
3. Ask the subject to take normal breaths through the mouthpiece for a short while.
4. After recording few normal breaths, ask the subject to take a deep forceful inspiration filling their lungs to their maximum ability followed by gentle exhalation. After that, the subject can resume normal breathing.
5. After a few normal breaths, ask the subject to expire quickly, forcibly and as completely as possible. Once this forceful expiration is complete, the subject inhales and resumes normal breathing.
6. Finally, ask the subject to take a deep forceful inspiration followed immediately by a maximum, quick and forceful expiration. Once this is complete, ask the subject to breath normally for a short time.
7. The spirogram is recorded on a moving drum, Fig-8. An example of how the recording is done is shown in Fig-9.

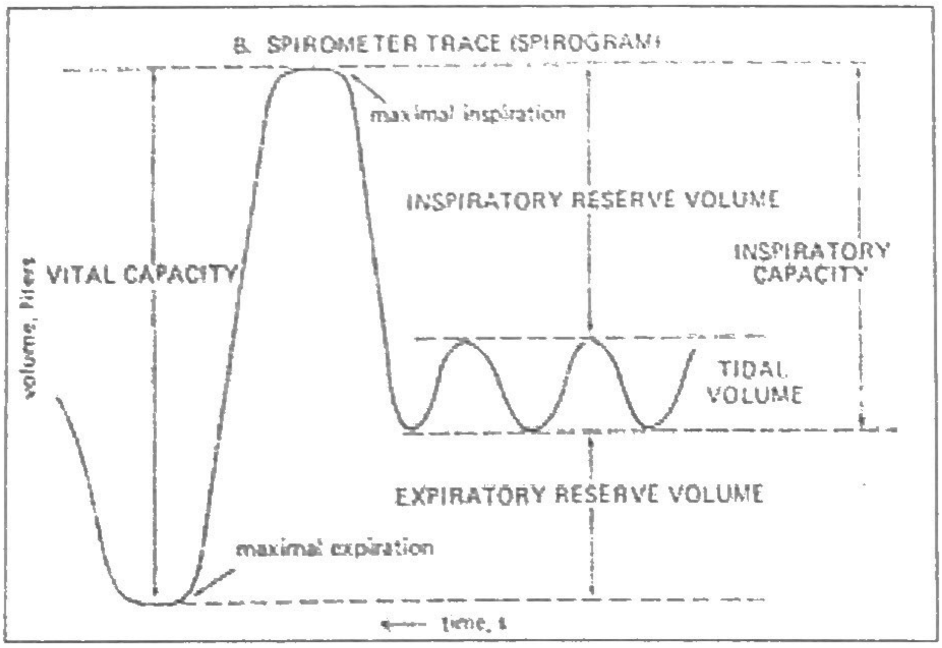


Figure 8. A spirogram recording. The deflection of the pen upwards or downwards with each phase of respiration is dependent on machine mechanics and is subject to variability.

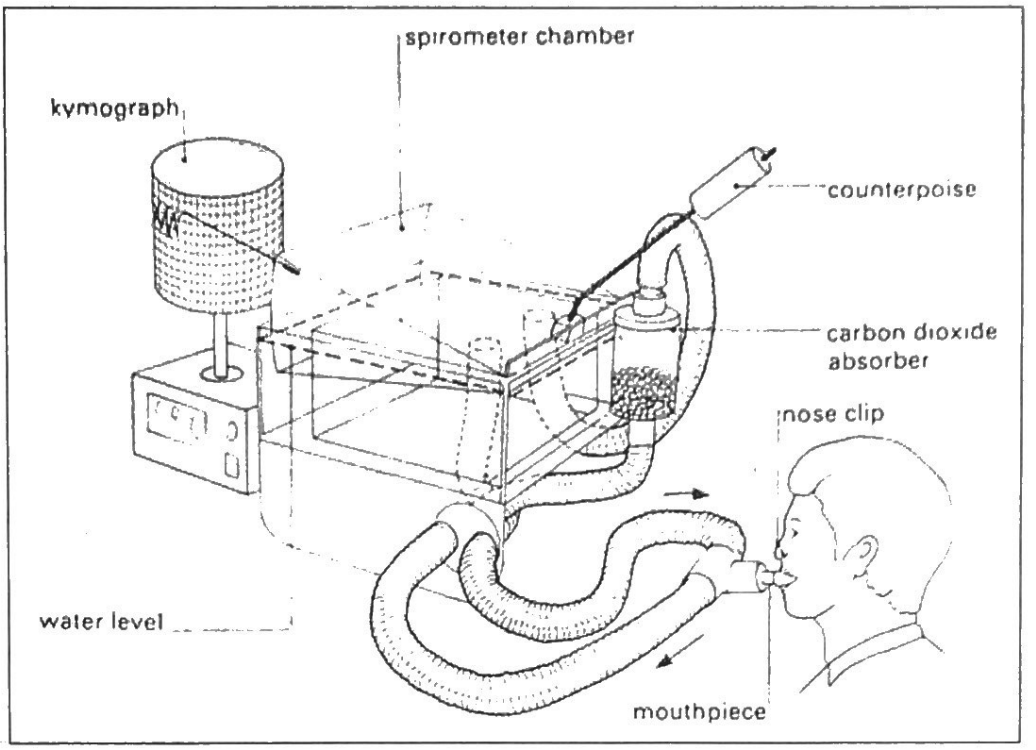


Figure 9. Simple lung volumes. The subject breaths through a mouthpiece while a nose clip is placed on the nose to avoid air escaping through it. While breathing, air moves in and out of the spirometer chamber causing displacement in the pen attached to it surface. The moving pen draws the spirometry graph on the kymograph. The degree of displacement is proportional to the volume of air moving in and out of the lungs. With proper calibration, the volume of air moving in and out of the lungs can be calculated.

Note to students

Depending on the mechanics of the machine used for simple spirometry measurements, the inspiratory/expiratory curves may be recorded upwards or downwards. The direction of inspiration and/or expiration will always be highlighted in any simple spirogram recording.

1.4. Practice questions

1. Define the following terms and state/calculate their values from the data collected in the lab:
    a. Tidal volume (TV).
    b. Expiratory reserve volume (ERV).
    c. Inspiratory reserve volume (IRV).
    d. Vital capacity (VC).
    e. Inspiratory capacity (IC).

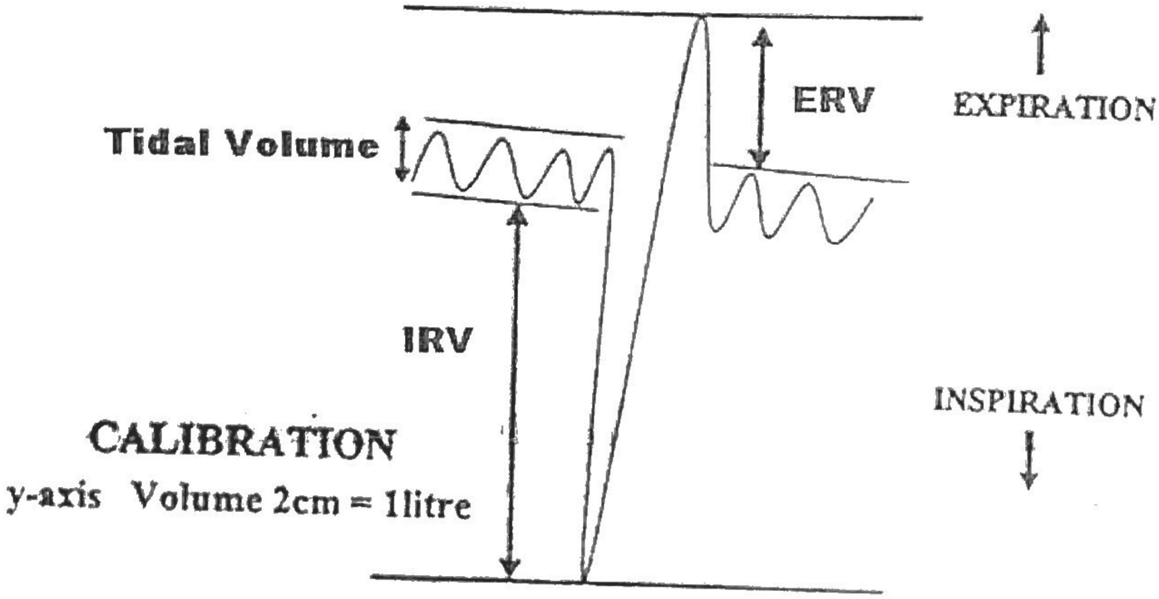
2. Name a few physiological factors that may influence lung volumes and capacities and how do they exert their effects?

3. Lung volumes and capacities are altered in a variety of pathological conditions. Name a few and explain how do these conditions bring about the changes are in lung volumes and capacities.

4. What is the physiological significance of the residual volume and the functional residual capacity?

5. Residual volume cannot be directly measured by spirometry. What is the technique that can be used to measure it? Explain how it works.

6. Using a simple ruler and the calibration provided in the graph, calculate the TV, IRV, ERV and VC from the graph below.



Parameter	Volume in liters
TV	
IRV	
ERV	
VC	

Practical 2. Dynamic Spirometry

2.1. Objectives

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

1. Perform a dynamic spirometry test on a fellow student.
2. Describe the two graphs recorded by dynamic spirometry, namely: flow-volume loop (FVL) and the volume-time curve (forced expiratory curve "FEV_1" curve).
3. Analyze the components of each graph; FVL and FEV_1 and describe the characteristics of a normal FVL and FEV_1 graphs.
4. 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.
5. 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}).
6. Discuss the indications of dynamic spirometry in clinical practice.
7. State the normal values for FEV_1, FVC and the FEV_1/FVC ratio.
8. State the normal values of FVC, PEFR, PIFR and MEF_{50} in FVL.
9. Describe the expected changes in FVL and FEV_1 curve in obstructive vs restrictive lung disease conditions.
10. Describe the expected changes in FEV_1, FVC and the FEV_1/FVC ratio in obstructive vs restrictive lung disease conditions.
11. Describe the expected changes in FVC, PEFR, PIFR and MEF_{50} in obstructive vs restrictive lung disease conditions.

2.2. Equipment

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

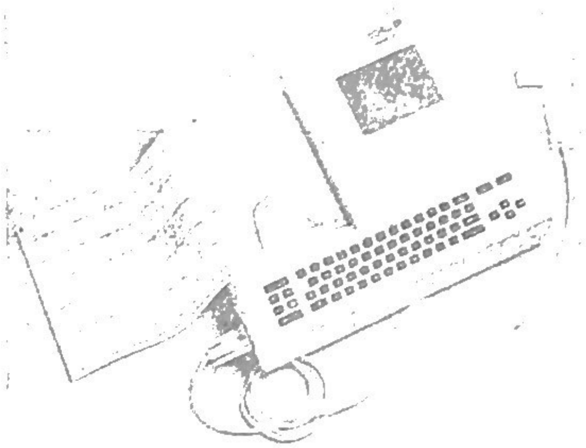


Figure 10. Automated spirometer.

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.

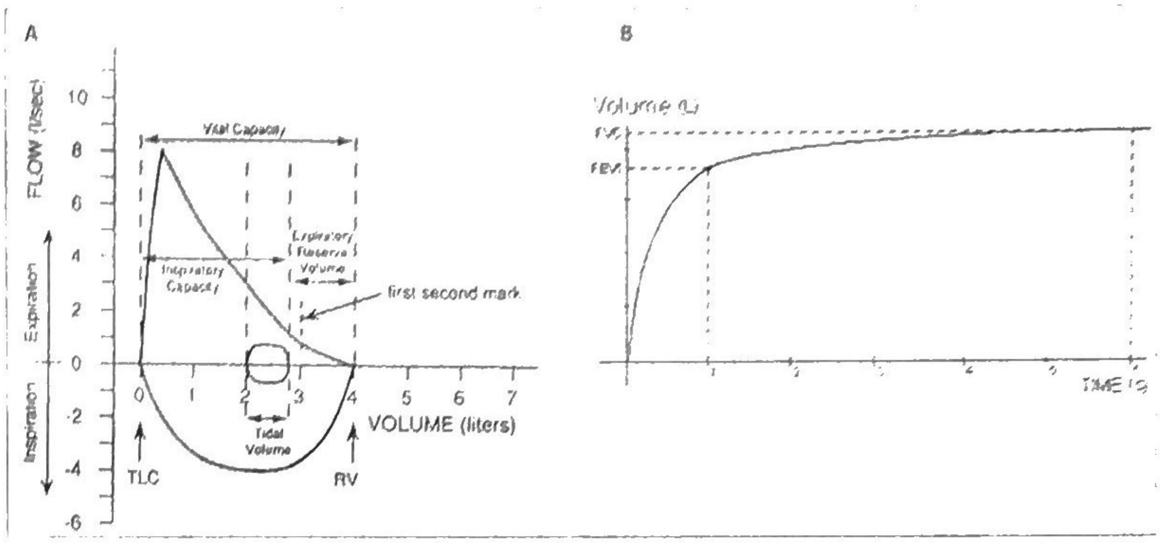


Figure 11. **Dynamic spirometry graphs.** (A) Flow-volume loop, (B) FEV1 curve.

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.

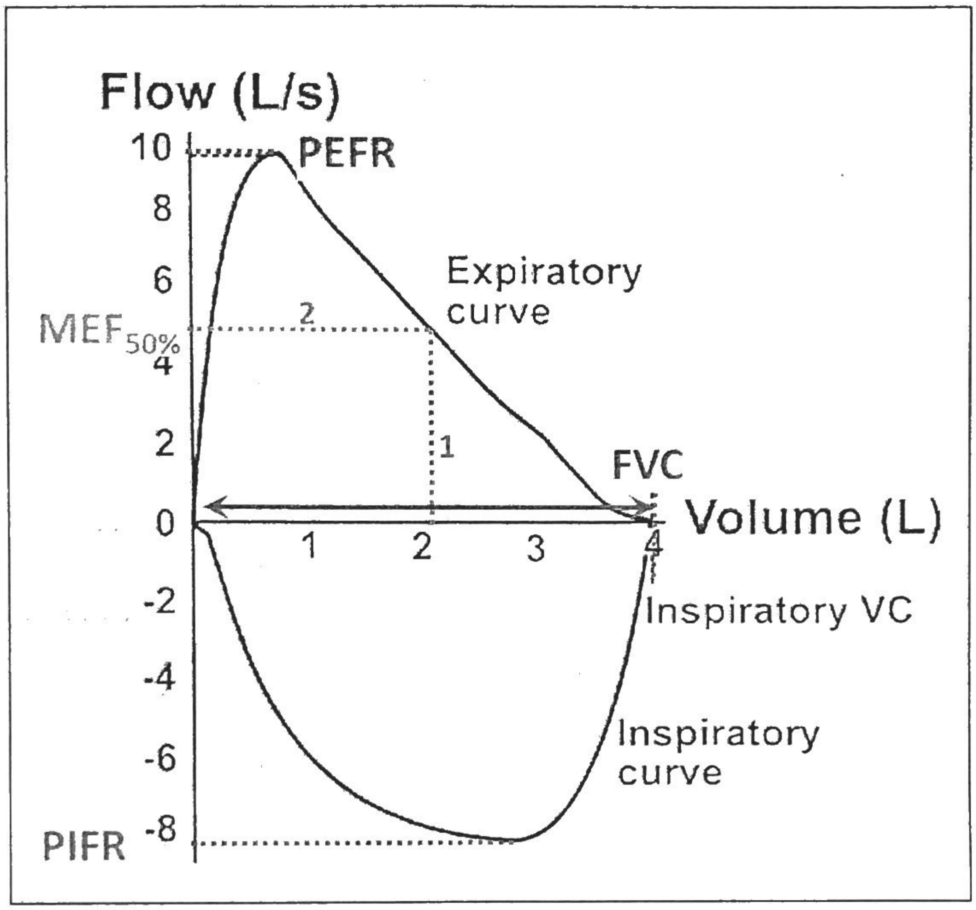


Figure 12. A normal flow-volume loop. The expiratory portion of the loop lies above the x-axis while the inspiratory potion of the loop lies below the x-axis. PEFR represents the maximal flow achieved during forced expiration while the PIFR represents the maximal flow achieved during inspiration. The 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 $MEF_{50\%}$.

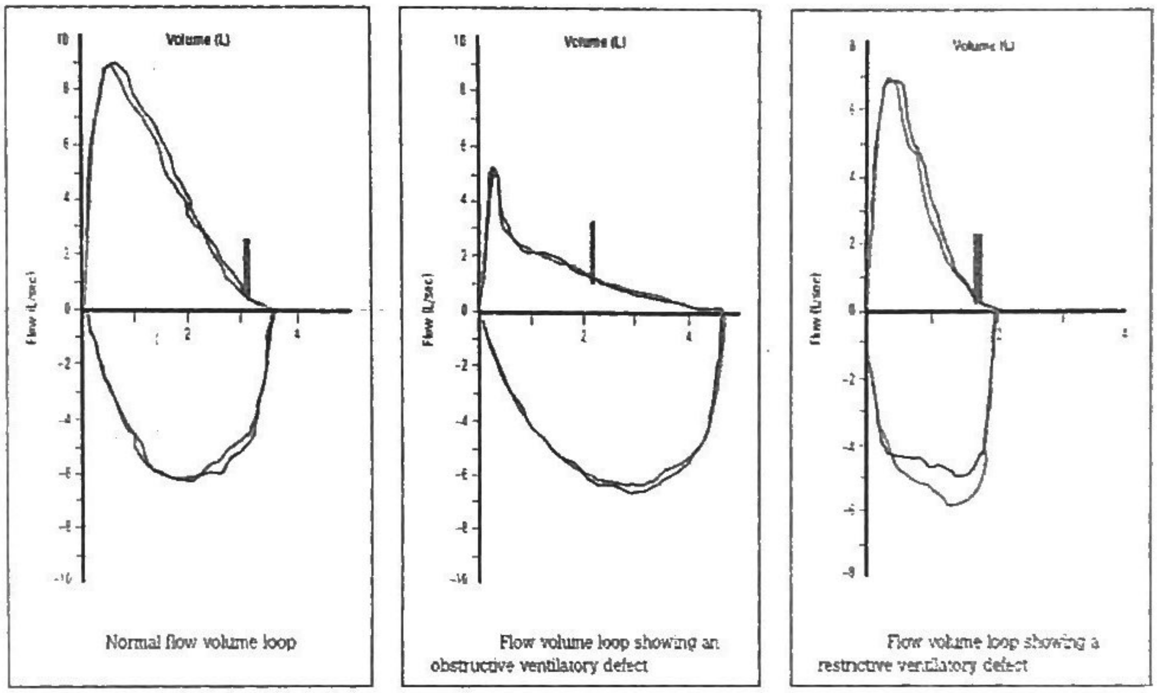


Figure 13. Shows a normal compared to FVLs of patients with obstructive and restrictive pulmonary disorders (reprinted from (2).

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).

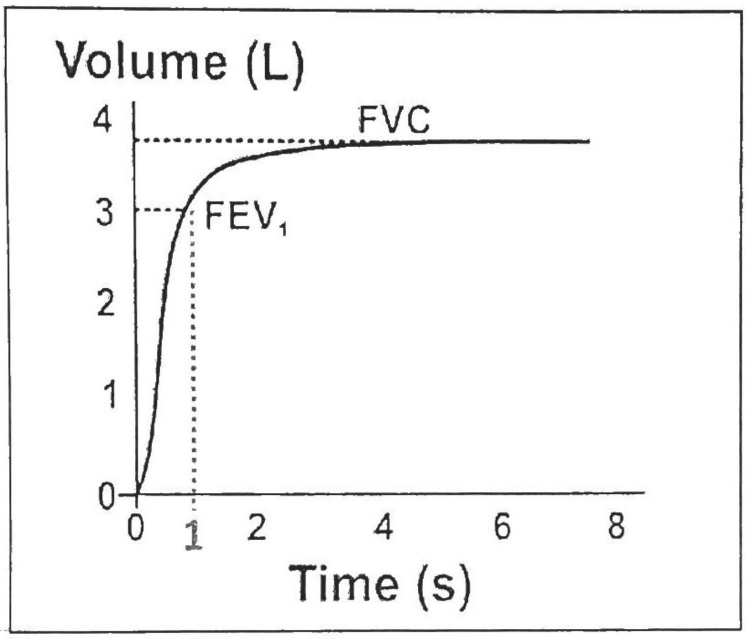


Figure 14. A normal volume-time graph (FEV_1 curve). The FVC represents the volume of air expired at the plateau. FEV_1 is the volume of air expired after 1 second of forced expiratory effort. Under normal conditions, more than 70% of the FVC is expired during the first second of expiration and this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

____

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

____

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

____

____

____

____

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.

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

8. What is the clinical significance of MEF50 measurements?

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.

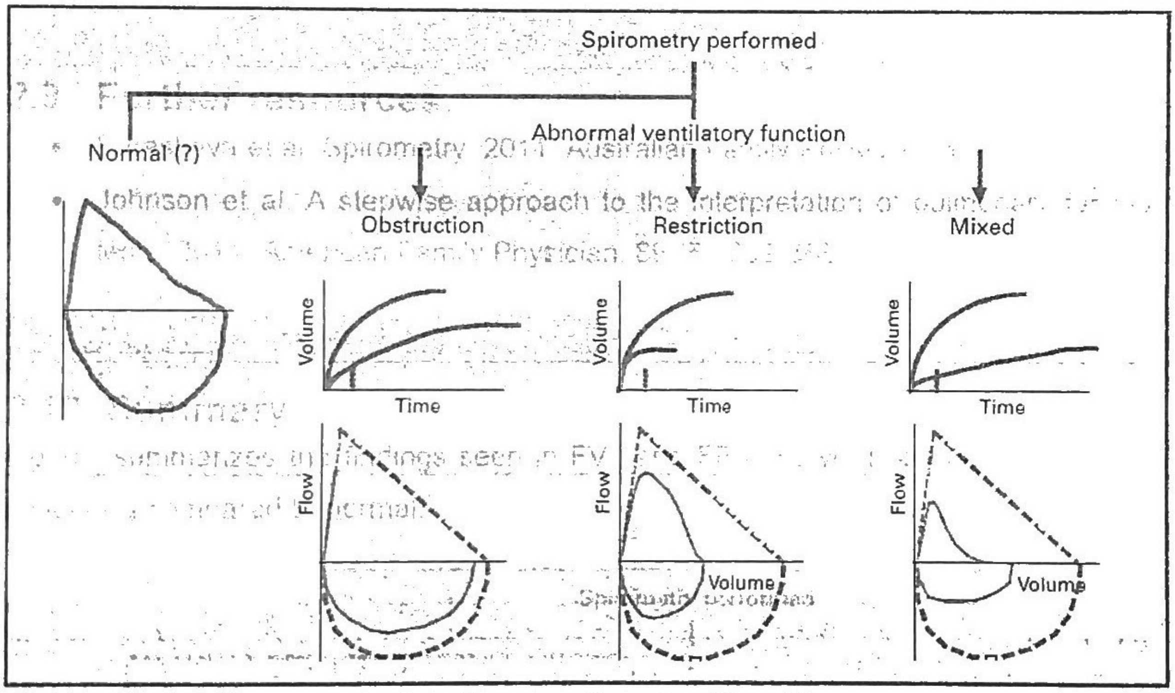


Figure 15. Typical spirograms and FVL in different ventilatory conditions (5).

References

1. Parker MJ. Interpreting spirometry: the basics. Otolaryngol Clin North Am. 2014;47(1):39-53.
2. Paraskeva MA, Borg BM, Naughton MT. Spirometry. Aust Fam Physician. 2011;40(4):216-219.
3. Barriero TJ, Rerillo I. An approach to interpreting spirometry. Am Fam Physician. 2004;69(5):1107-1114.
4. Johnson JD, Theurer WM. A stepwise approach to the interpretation of pulmonary function tests. Am Fam Physician. 2014;89(5):359-366.
5. Pierce R. Spirometry: an essential clinical measurement. Aust Fam Physician. 2005;34(7):535-539.