Chapter 5 - Dynamic Lung Volumes and Flows

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Professional Skills

Upon completion of this chapter, the reader will be expected to:

- Define the commonly used terms for dynamic volumes and flows
- Understand the principles of operation of a variety of volume and flow measuring devices used to assess dynamic volumes and flows
- Perform measurements of dynamic volumes and flows to the required national standards, and be able differentiate between poor patient performance and equipment problems
- Understand the applications of dynamic volumes and flows in routine clinical practice

5.1 Introduction

A number of respiratory disorders can alter the mechanical properties of the respiratory system, the most important effects being upon airway resistance and lung compliance. Simple tests in which volumes and flows are measured during forced expiratory and inspiratory manoeuvres are valuable in the detection of the mechanical abnormalities associated with respiratory disorders. The use of spirometry to assess airway function and lung volume is the basic screening tool for respiratory abnormality. Spirometry has developed considerably since the time of Hutchinson (1846) and has moved away from bench-top water spirometers towards hand held devices using as variety of technologies chiefly measuring flow and deriving volume with respect to time.

5.2 Definition of Terms/Symbols/Units

The following tests are in common use:

a) **Peak Expiratory Flow** - used to indicate the presence of airflow obstruction (variable or fixed) as seen in patients with COPD or asthma.

b) **Forced Vital Capacity and Forced Expiratory Volume in 1 second** - indicates the type of respiratory disease (i.e. restrictive or obstructive) and the severity of airflow limitation.

c) **Relaxed Vital Capacity** - used as a very simple measure of the size of the lungs and may be reduced in both obstructive and restrictive disorders.

d) **Maximal Flow-Volume Curves** - used to distinguish different types of airflow obstruction and can show the presence of small airway disease.

These tests have largely superseded the Maximum Voluntary Ventilation. The most commonly used terms used in spirometry are:

Peak Expiratory Flow (PEF) [$l.sec^{-1}$ or $l.min^{-1}$]: The maximal flow achievable from a forced expiration with an open glottis starting from a position of full inspiration. The addition of the word "rate" after Peak Expiratory Flow is unnecessary.

Peak Inspiratory Flow (PIF) [$l.sec^{-1}$ or $l.min^{-1}$]: The maximal flow achievable from a forced inspiration with an open glottis starting from a position of full expiration. The addition of the word "rate" after Peak Inspiratory Flow is unnecessary.

Forced Expiratory Volume in 1 second (FEV_1) [l]: The maximal volume of gas, which can be expired from the lungs in the first second of a forced expiration from a position of full inspiration. The FEV may be recorded at any time "x" during the forced expiration; thus, $FEV_{0.5}$ is the volume expired in the first 0.5 second and $FEV_{6.0}$ is the volume expired in the first 6 seconds and is becoming popular in monitoring patients with COPD.

Forced Vital Capacity (FVC) [l]: The maximal volume of gas that can be expired from the lungs during a forced and complete expiration from a position of full inspiration.

Forced Inspiratory Vital Capacity (FIVC) [l]: The maximal volume of gas that can be inspired during a forced and complete inspiration from a position of full expiration.

Relaxed Vital Capacity (RVC) [l]: This can be measured in two ways:

1. *Expiratory Vital Capacity (EVC) [l]:* The maximal volume of gas that can be expired from the lungs during a relaxed but complete expiration from a position of full inspiration.

2. *Inspiratory Vital Capacity (IVC) [l]:* The maximal volume of gas that can be inspired into the lungs during a relaxed but complete inspiration from a position of full expiration.

Forced Expiratory Flow [$l.sec^{-1}$ or $l.min^{-1}$]: The maximal flow achievable when 25%, 50% and 75% of the FVC has been exhaled. Normally quoted as FEF_{25}, FEF_{50} and FEF_{75} respectively.

Forced Inspiratory Flow [$l.sec^{-1}$ or $l.min^{-1}$]: The maximal flow achievable when 25%, 50% and 75% of the FIVC has been inhaled. Normally quoted as FIF_{75}, FIF_{50} and FIF_{25} respectively.

Maximal Voluntary Ventilation (MVV) [$l.min^{-1}$]: The volume of air in a specified period during repetitive maximal respiratory effort. This is also known as the Maximal Breathing Capacity (MBC). A rough guide to this value is 35 x FEV_1 in normal subjects.

5.6.4 Maximal Flow Volume Curves

The definition of a maximal flow volume curve is the graphical presentation of the flow versus volume signal recorded from a maximal forced expiration, starting from full inspiration, which is immediately followed by a maximal forced inspiration. This is performed as one manoeuvre. Flow volume curves thus involve the simultaneous measurement of flow and volume during forced expiration and inspiration. The equipment for measuring these curves is required to have a large graphical display and a good frequency response and should be capable of measuring flow rates of up to 12 $l.s^{-1}$. Most commonly, flow volume curves are measured directly using a flow measuring pneumotachograph but may be measured indirectly using a volume measuring device such as a dry rolling seal spirometer.

The shape of the flow volume curve can aid in the recognition of different types of abnormality such as emphysema and intra- or extra-thoracic airflow obstruction. Curvilinearity of the MEFV curve is a good indicator of mild intrathoracic airflow obstruction. Fixed and dynamic obstruction of the extrathoracic airway can be detected by distinctive patterns of MEFV and MIFV. Respiratory muscle weakness also produces distinctive changes in MEFV and MIFV curves. A range of flow volume curve appearances is shown in Figures 5.12 and 5.13. Partial flow volume curves have been used to indicate the difference between flows at low lung volumes before and after the relaxing effect on airway tone of a full inhalation. The procedure is for the subject to take a small breath in from the room, insert a mouthpiece, and perform a maximal expiratory blow from this point until no more gas can be exhaled from the lungs. The subject then inhales to the point of full inspiration and performs a maximal forced expiratory manoeuvre again. Such a manoeuvre is useful to perform in asthmatic subjects.

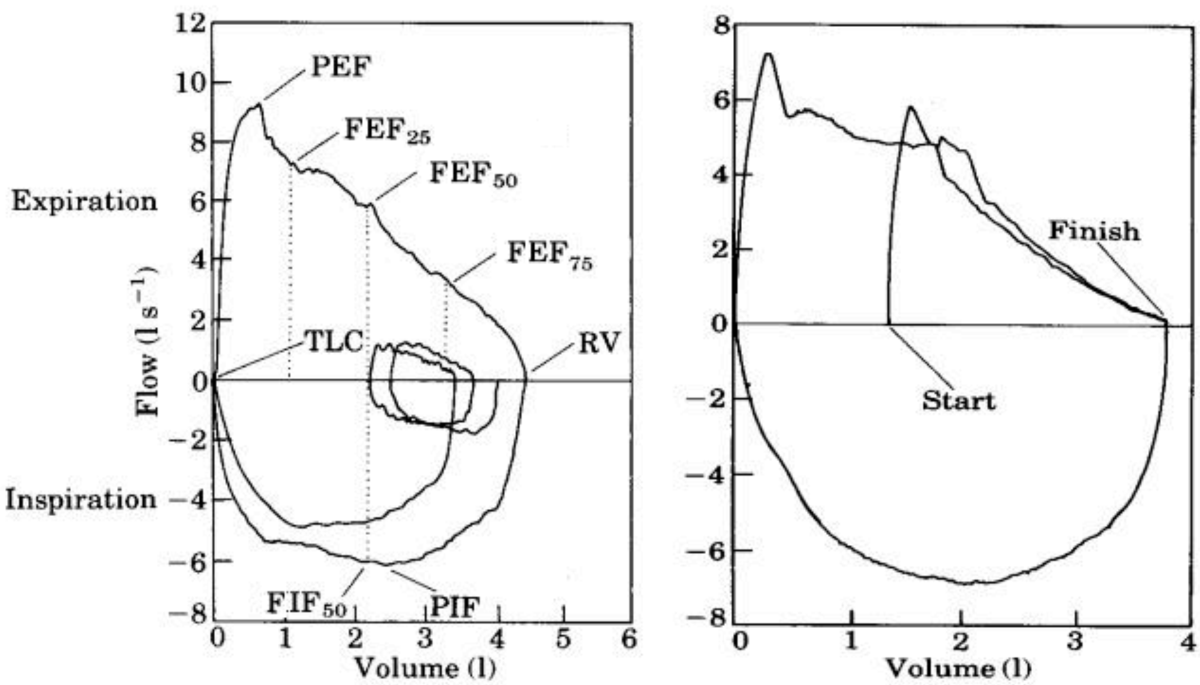

Figure 5.12 Example of flow volume curves in a normal subject with two tidal breaths preceding the loop. In normals, the flow trace between PEF and FEF_{25} is approximately a straight line, due to the relative homogenous emptying of the lungs. In the curve on the right, a partial flow volume loop followed by a full flow volume loop. The starting position of the partial loop should start from a point below full inspiration, which is at least equal to 20% of the full FVC.

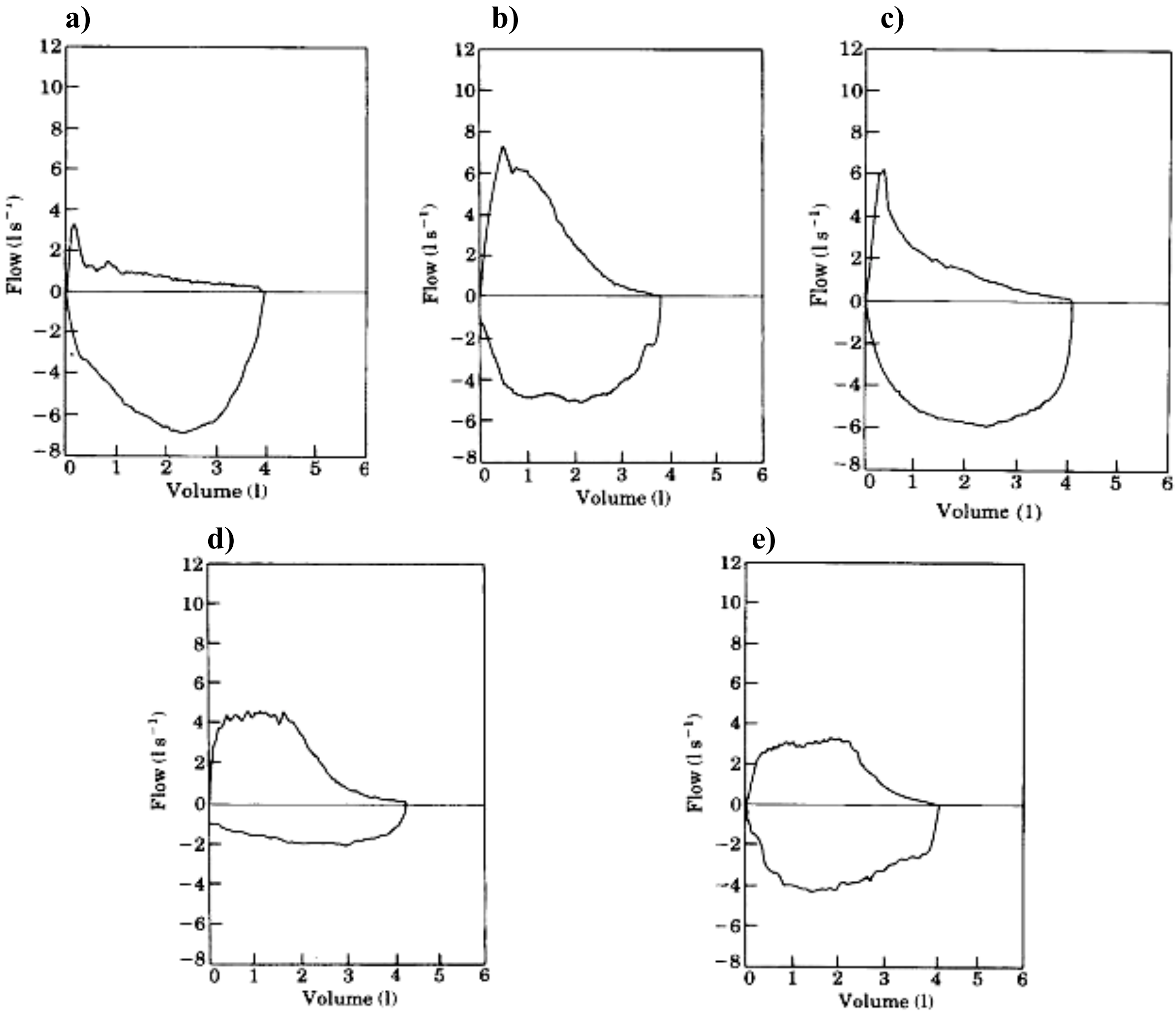

Figure 5.13 a) A patient with chronic obstructive pulmonary disease showing early collapse of the large airways and a sudden drop in flow early in the expiratory part of the manoeuvre. The inspiratory limb is unaffected as the airways are being opened up by transmural pressure; **b)** an example of a flow volume loop from an elderly subject showing the curvilinearity in the latter part of the expiratory limb; **c)** a patient with asthma shows a smooth curvilinear drop in flow with respect to volume indicating intrapulmonary airflow limitation. The inspiratory limb is relatively unaffected; **d)** variable extrathoracic upper airway obstruction due to goitre showing decapitation of the expiratory part of the loop with more extreme limitation of the inspiratory limb due to collapse of the trachea during inspiration; **e)** intrathoracic central airway obstruction showing decapitation of the expiratory limb of the loop but little, if any, reduction in the inspiratory limb. This was due to an intrathoracic retrosternal goitre.

5.6.5 Maximum Voluntary Ventilation

MVV has been superseded by FEV_1, which is a less tiring and more repeatable procedure. However, MVV is valuable in certain diseases where the inability to maintain a given ventilation rate during the test may be a helpful observation in patients with suspected neuromuscular disorders. This manoeuvre requires a spirometer that is a capable of recording respiratory cycles for at least 15 seconds.

The test is focused on the overall function of the respiratory system and may be affected by abnormalities of resistance, respiratory muscle function, and chest wall or lung compliance. In normal healthy male subjects, values obtained are between 150L/min and 200L/min (marginally