REVIEW ARTICLE

PATTERN IDENTIFICATION OF OBSTRUCTIVE AND RESTRICTIVE VENTILATORY IMPAIRMENT THROUGH FLOW VOLUME CURVES

Ashraf Husain, Syed Shahid Habib

Department of Physiology, King Khalid University Hospital, King Saud University, Kingdom of Saudi Arabia

Respiratory system performs functions of ventilation (V), perfusion (Q), and diffusion (DL). All respiratory function tests are based on the measurement of these functions. Spirometry measures the mechanical function of the lung, chest wall, and respiratory muscles by assessing the total volume of air exhaled from a full lung (total lung capacity [TLC]) to an empty lung (residual volume). This volume, the forced vital capacity (FVC) and the forced expiratory volume in the first second of the forceful exhalation (FEV_1), should be reproducible to within 0.15 L upon repeat efforts unless the largest value for either parameter is less than 1 L. Flow-volume loop recording is one of the dynamic ventilatory function tests. This is a safe, simple and reproducible. It is performed routinely in general practice. The shape of the flow-volume loop can differentiate between normal or abnormal lung function. Abnormalities like obstructive or restrictive lung conditions can be differentiated. Although these tests cannot give a pathological diagnosis and assesses the mechanical functional impairment of various respiratory conditions, but they support other respiratory function tests. Moreover, they are important prognostic indicators of disease process and are commonly used to monitor drug therapy. This review explains the interpretation of flow volume curves in health and disease which will provide an easy guide for both clinicians and physiologists.

Keywords: Spirometry, FEV1, FVC, Obstructive lung disease, Restrictive lung disease

INTRODUCTION

Respiratory system has functions namely ventilation (V), perfusion (Q), and diffusion (DL). All respiratory function tests are based on the measurement of these functions. Flow-volume loop recording is one of the dynamic ventilatory function tests. This is a safe, simple and reproducible. It is performed routinely in general practice. The shape of the flow-volume loop can differentiate between normal or abnormal lung function. Reduction in the amount of air exhaled forcefully in the first second of the forced exhalation (FEV_1) may reflect reduction in the maximum inflation of the lungs (TLC), obstruction of the airways, loss of lung elastic recoil, or respiratory muscle weakness. Airway obstruction is the most common cause of reduction in FEV_1. Response of FEV_1 to inhaled bronchodilators is used to assess the reversibility of airway obstruction. Abnormalities like obstructive or restrictive lung conditions can be differentiated. These tests cannot give a pathological diagnosis; it only assesses the mechanical functional impairment of various respiratory conditions.

Indications:[1,2]

1. To diagnose the causes of shortness of breath and cough.
2. To find out early evidence of lung dysfunction.
3. Quantify the loss of lung function due to either obstructive or restrictive ventilatory impairment.
4. To follow up and assess the response to therapy.
5. To evaluate respiratory function before surgery to have an idea of how well the person can tolerate the surgery.
6. To monitor the occupational exposures to substances like asbestos, coal dust, etc.

Normal flow-curve (Figures 1-3):

It is performed in the same way as forced vital capacity (FVC) with maximal inspiration and maximum expiratory effort. The record is plotted by x-y recorder. On vertical axis (Y axis) flow in litres/second while on horizontal axis (X-axis) volume in litres is recorded.

The person is first instructed and then practices two or three times before the final record is plotted. The record thus constructed has an inspiratory part and an expiratory part of the loop. The triangular part denotes the expiratory loop and a semicircular part represents the inspiratory segment of the loop.

The test is repeated over again after the person has been given bronchodilator. Then measures the degree of reversibility. The results of the test are then compared against a reference values according to age, sex and height for correct interpretations.[3,4]

The flow volume curve represents an effort dependent and effort independent part of the curve.[5,6] All the inspiratory loop and early nearly vertical part of the expiratory loop (peak expiratory flow) are effort dependent that means it depends on muscular effort. This is followed by a linear part of the curve. After about one third of this linear part of the curve is not influenced by any increase in muscular effort and is known as muscle independent part of the loop. This is due to dynamic compression of the airways and the flow of air at this time is due to interaction of the elastic recoil and the airway resistance in the peripheral air passage. The distance between the start and the end of loops on x-axis represents vital capacity. The maximum expiratory flow rate at 75, 50 and 25% of vital capacity is measured in litres/second (Figure-3).[7,8]

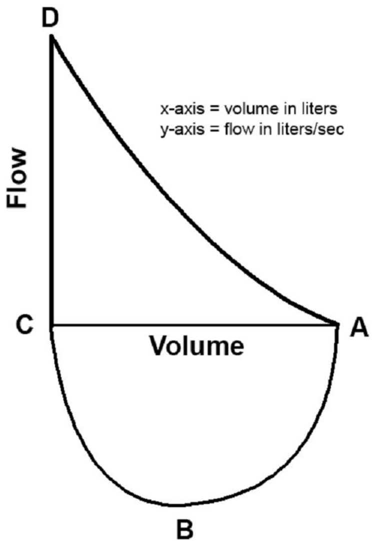

Figure-1: Normal flow volume loop.
ABC=inspiratory part of the loop (oval);
ACD=expiratory part of the loop (triangular);
ABCD=muscle dependent part of the loop;
DA=effort (muscle) independent part of the loop;
AC=vital capacity;
CD=peak expiratory flow (PEFR).

Abnormal patterns of flow-volume curve

The shape of the flow-volume curve gives a clear idea whether it records are normal or abnormal. The abnormalities are either due to obstructive or restrictive ventilatory impairment (Figure-4).

The severity of reductions in the FVC and/or the FEV_1 can be characterized by the following scheme:

- Mild: 70–79% of predicted
- Moderate: 60–69% of predicted
- Moderately severe: 50–59%
- Severe: 35–49% of predicted
- Very severe: Less than 35% of predicted

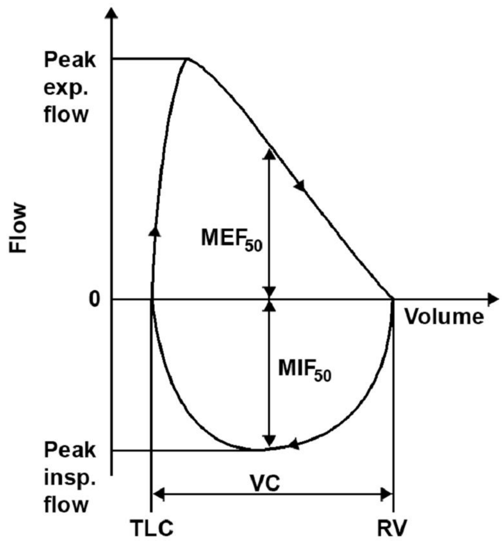

Figure 2: Normal flow volume loop.
MEF50=maximum expiratory flow at 50% of VC;
MIF50=maximum inspiratory flow at 50% VC;
VC=vital capacity;
TLC=total lung capacity;
RV=residual volume.

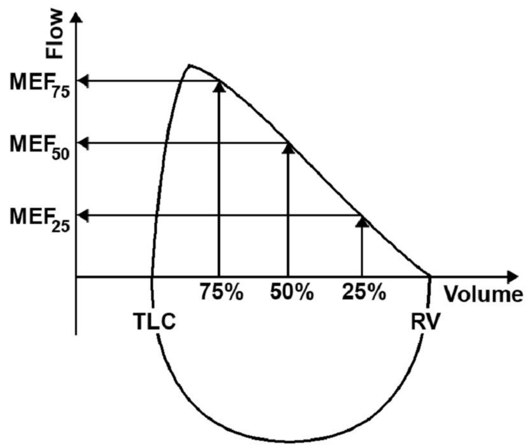

Figure-3: Normal flow volume loop. Maximum expiratory flow rate at 75, 50, and 25% of vital capacity.

Obstructive ventilatory disorders[9] are characterized by airway narrowing which increases the time it takes to empty from the lungs. Examples of obstructive airway diseases are asthma, chronic bronchitis, chronic obstructive pulmonary disease (COPD) and emphysema (Figure-5). The flow-volume curve provides the information about the level of obstruction such as intrathoracic or extrathoracic, fixed or variable reversibility to bronchodilators.[10]

A) Central obstructive pattern in the major air passage and they are:

I. Extra-thoracic obstruction (Figure-6): The flow volume curve shows features of obstruction during inspiratory phase of the curve. The inspiratory part of the curve is flattened while the expiratory part remains normal (triangular) and there is substantial reduction of the PIF (peak inspiratory flow), this is due to the extra-thoracic airways tends to collapse during inspiration as the pressure within the airways is always negative during inspiration. In extrathoracic obstruction, when the lumen is narrow during inspiration and the narrowing is further increased around the site of the narrowing hence the inspiratory flow is reduced in comparison to the expiratory flow. Such type of flow-volume pattern is seen, vocal cord paralysis, extrinsic compression from cervical tumour, goiter, etc.

II. Intra-thoracic airway obstruction (Figure-7): The obstruction is seen during expiration leading to flattening of the expiratory part of the curve while inspiratory part of the loop is normal.

III. Fixed upper airway obstructive like tracheal stenosis shows flattening of the curve during both the inspiratory and expiratory phases of this curve. In this both the inspiratory and expiratory part of the loop are truncated (Figure-8).[11,12]

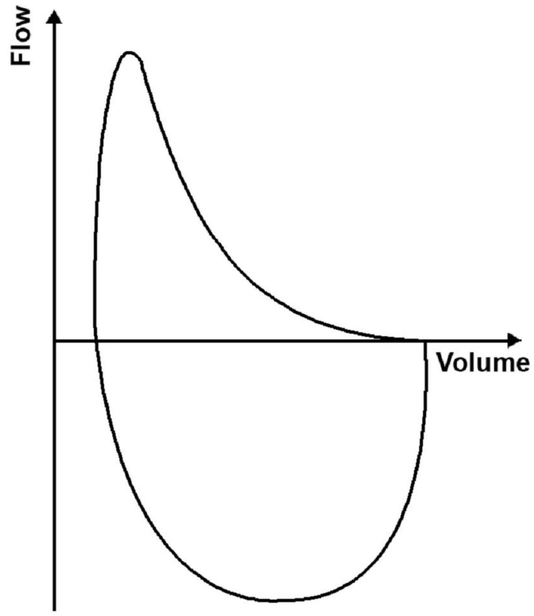

Figure-4: Moderate degree of airway obstruction.

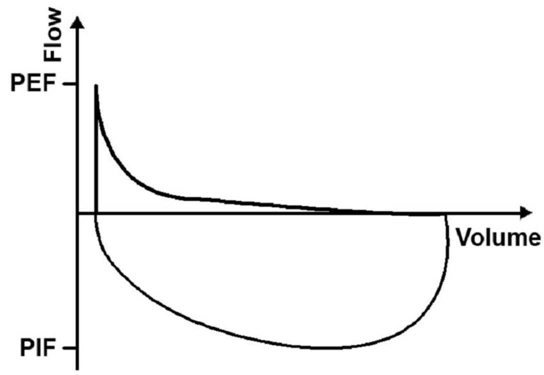

Figure-5: Severe airways obstruction (e.g., emphysema).

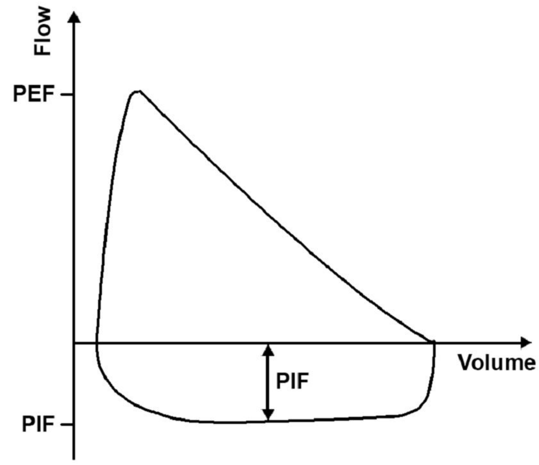

Figure-6: Extracellular obstruction (e.g., tracheal involvement above the sternal notch).

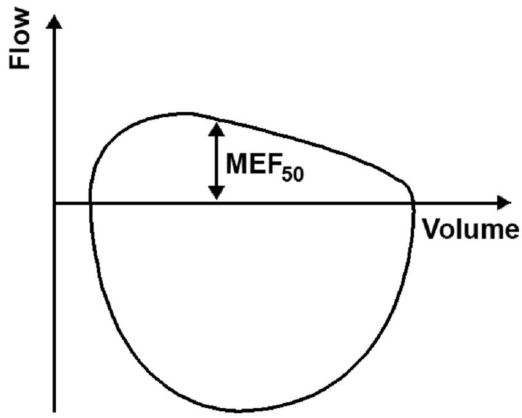

Figure-7: Intrathoracic obstruction.

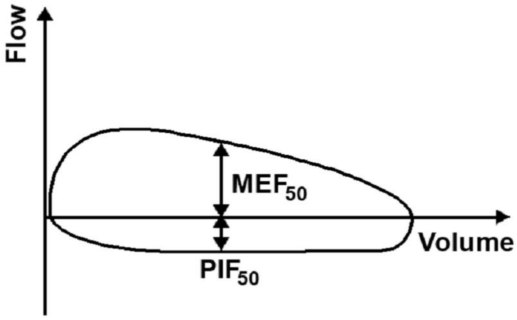

Figure-8: Fixed airway obstruction.

B) Peripheral airways obstruction: The conditions like asthma and emphysema can easily be distinguished by the recording of flow volume curve. In asthma after bronchodilator inhalation, there is significant degree of reversibility, while in emphysema there is no or minimal reversibility. Pattern identification is very useful in differentiating the various respiratory abnormalities. The triangular phase of the record is the expiratory recording. This is divided into straight or ascending limb and denotes peak flow rate (effort dependent). This ascending limb of the curve is followed by a slightly curvilinear shape of the descending limb of the curve (effort independent). In obstructive ventilatory conditions, both these two components are affected. The near vertical part of the curve which measures the peak expiratory flow rate and the slightly curvilinear part of the curve which follow it represents effort independent part of the curve. When there is expiratory obstruction, this curvilinear and the vertical components are affected. The inspiratory portion of the maximum flow volume curve is more sensitive to major control airways obstruction than the expiratory limb of the curve. In mild to moderate obstruction curvilinear part of the curve becomes concave. The concavity of the curve faces outwards and the peak expiratory flow rate is also reduced. In severe airways obstruction (emphysema),[13] the curvilinear part of the expiratory limb collapses soon after the peak expiratory flow rate and this itself is greatly reduced. This is because flow rate at lower lung volumes depend on the elastic record pressure of lungs and the airway resistance developed distal to the point at which dynamic compression occurs.[14]

In summary, the narrowing of the airway outside the thorax (upper trachea or larynx causes predominantly obstruction during inspiration whereas intrathoracic obstruction limits expiration.[15] The flow volume curve is highly sensitive method of detecting these differences.

It can also be mentioned that maximum expiratory flow at 50% of vital capacity (MEF: 50% or FEF: 25–75%) is the best measurement of small airway obstruction while peak expiratory flow rate (PEFR) is used and mainly reflect large airways involvement. Since PEFR is effort dependent, it is also used in assessing the strength of respiratory muscles.[16]

C. Restrictive ventilatory disorders: In such conditions the lung is unable to expand up to normal limits. This results in reduction of FVC, FRC, RV, FEV_1 and PEFR values. The FEV_1 to FVC ratio remains normal (80%). This is due to the fact that airway resistance remains normal, and there is a proportionate reduction in the values of FEV_1 to FVC. The flow volume curve has an outline similar to the normal record but in reduced size, e.g., miniature of the normal shape. Over all shape is small and oval in outline. The curve descends in a straight line from the peak expiratory flow level to the x-axis of the curve (Figure-9).

Examples of restrictive lung disease are pulmonary fibrosis, pneumonias, pleural effusion, obesity, damage to the nerve supply to the respiratory muscle, etc.

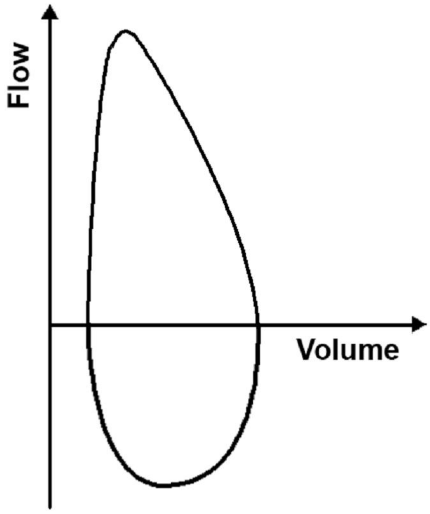

Figure-9: Restrictive ventilatory impairment (e.g., lung fibrosis).

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Address for correspondence:

Prof. Ashraf Husain, Consultant and Head of Clinical Physiology Unit, Department of Physiology (29), College of Medicine, PO Box 2925, King Saud University, Riyadh 11461, Kingdom of Saudi Arabia. Tel: +966-1-4671607 Fax: +966-1-4671041
Email: ashrafhusain31@hotmail.com