Assessment of pulmonary function

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Abstract

Assessment of pulmonary function plays a vital role in the investigation and monitoring of patients with and at risk of respiratory disease. The interpretation of pulmonary function tests requires knowledge of respiratory physiology and should always be made within the context of the patient's history and examination findings. This article discusses the measurement and interpretation of commonly used pulmonary function tests including spirometry, lung volume and gas transfer measurements and exercise testing.

Keywords Gas transfer; lung; lung volumes; obstruction; physiology; pulmonary function tests; spirometry

Key points

- There are a number of contraindications to pulmonary function tests. In particular, testing should be avoided in patients with current pulmonary infections as there is a risk of cross-contamination
- When interpreting spirometry results, the forced expiratory volume in 1 second (FEV_1) to forced vital capacity (FVC) ratio (FEV_1/FVC) is used to determine whether there is an obstructive or restrictive defect. With an obstructive pattern, the severity of obstruction can be determined by comparing the FEV_1 with predicted values
- Measurement of lung volumes using the plethysmography (body box) and dilution methods can be useful in patients with bullous lung disease: the dilution method measures lung volumes only in ventilated lung, whereas plethysmography includes the volume of non-communicating areas such as bullae
- Pulmonary function tests should be measured in all patients under consideration for lung resection. Patients considered to be at high risk of postoperative complications can be further assessed using exercise testing

Introduction

Pulmonary function tests (PFTs) are invaluable for diagnosis and monitoring of respiratory diseases such as chronic obstructive pulmonary disease (COPD) and pulmonary fibrosis. Knowledge of lung physiology is needed for interpretation.

Lung physiology

The lungs are designed to aid the supply of oxygen to, and removal of carbon dioxide from, the body. Ventilation is the movement of air from the external environment to the alveoli, and gas exchange describes the movement of oxygen into the bloodstream and carbon dioxide into the alveoli. These functions are coordinated to work efficiently.

For ventilation, the lungs must generate sufficient negative pressure to move air down the airways to the alveoli and distribute it through the lungs. The main static lung volumes are shown in Figure 1. Any factor — exercise, disease, an unfavourable environment — that alters these volumes will affect the ability of the lungs to ventilate.

Ventilation

Ventilation is an active process — the primary muscle that contracts to enable inspiration is the diaphragm. As the diaphragm contracts, it shortens, moves downwards and moves the rib cage outwards. This increases the difference in pressure between the alveoli and pleural space (the negative pressure), so air flows into the lungs. Expiration can occur passively — when the muscles stop contracting at the end of inspiration, the elastic recoil of the lungs leads to a reduction in negative pressure, and air flows out of the lung. However, when respiratory demands increase (e.g. exercise), active contraction of the abdominal wall muscles and internal intercostals increases the outward flow of air.[1]

Gas exchange

Gas exchange requires the alveoli to be ventilated and perfused. Ventilation and perfusion increase in a cranio-caudal direction, so the basal alveoli are better perfused than the apical ones. Ideally, the amount of ventilation (V) will match the amount of perfusion (Q), to maximize gas exchange. However, because of gravitational and non-gravitational factors, ventilation, even in normal, healthy lungs, exceeds perfusion in the lung apices and vice versa in the lung bases (the V/Q ratio is highest at the apex and lowest at the lung bases), so V/Q matching is never perfect. In a ventilated, perfused alveolus, gas moves from high to low concentration, so oxygen will move from the alveoli to the blood, and carbon dioxide will move in the opposite direction. Gas exchange may be limited in this situation because of:[1]

- increased membrane thickness (e.g. fibrosis)
- loss of surface area (e.g. emphysema)
- reduced numbers of red blood cells to take up diffused oxygen (i.e. anaemia)
- reduced cardiac output (resulting in reduced pulmonary capillary volumes, including pulmonary emboli).

Preparing for pulmonary function tests

PFTs can be performed with the patient sitting or standing; the position should be recorded on the report. The seated position is preferred for safety. If standing is used, place a chair behind the patient in case of light-headedness. In obese patients, improved

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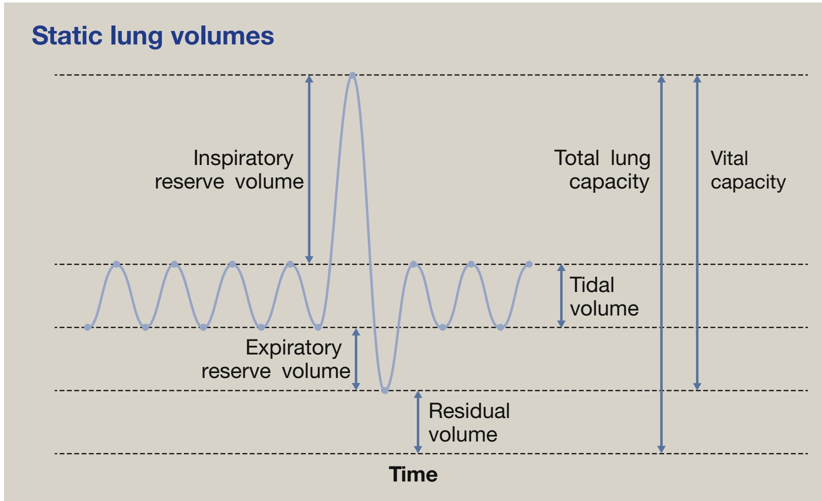


Figure 1

values may be seen with standing. False teeth should be kept in unless loose or preventing an adequate seal around the mouthpiece.

Contraindications to performing pulmonary function tests

PFTs require patient cooperation and effort. Confusion, inability to understand the instructions, pain, acute ill-health and stress incontinence may produce suboptimal tests. Specific contraindications to PFTs include current pneumothorax, recent cardiothoracic, abdominal or ophthalmic surgery, and recent myocardial infarction. Cross-contamination following PFTs has been reported so PFTs in patients with active respiratory infections such as tuberculosis should be deferred until the risk is minimized. In addition, extra precautions to disinfect equipment are needed. Activities that may result in a suboptimal reading and should be avoided are:

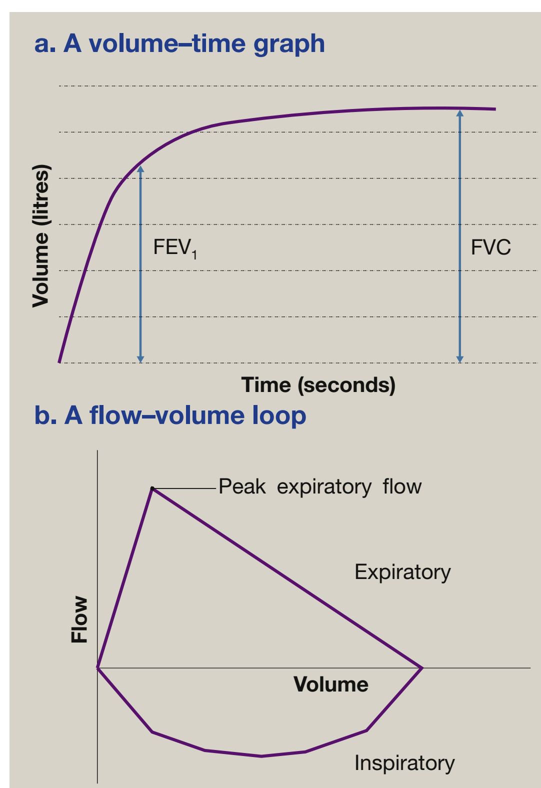
- drinking alcohol up to 4 hours before the test
- eating a large meal up to 2 hours before the test
- smoking up to 1 hour before the test
- vigorous exercise up to 30 minutes before the test.

Patients should also be advised not to wear tight, restrictive clothing as this may result in suboptimal readings.

Spirometry

Spirometry measures the volume and flow of air that can be inhaled and exhaled. The patient is asked to inhale maximally and then breathe out into the spirometer as hard and fast as possible for as long as possible. A minimum exhalation time of 6 seconds is usually needed, and the procedure is repeated at least three times to ensure consistent results.[2] Nose clips can be used to prevent air escaping and not being measured. If forced inspiratory measurements are needed (e.g. patients in whom upper airways obstruction is suspected), they can be recorded during inspiration. Results can be displayed as a volume–time graph or a flow–volume loop (Figure 2). This is used to calculate the forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio and peak expiratory flow rate (PEFR). FVC is the volume of air that can be maximally forcefully breathed out after full inspiration. It is the difference between total lung capacity (TLC) and residual volume (RV) (Figures 1 and 2a). FEV_1 is the volume of air that is breathed out in the first second of forced expiration (Figure 2a). In healthy individuals, FEV_1 and FVC will depend mainly on height, sex and age. Predicted value calculators are available, and predicted values will normally be quoted on the report. Reference should also be made to any previous readings.

The FEV_1/FVC ratio is used to differentiate between obstructive and restrictive defects. The Global Initiative for Chronic



FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity.

Figure 2