Tests of pulmonary function before thoracic surgery

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Abstract

Respiratory complications contribute significantly to perioperative morbidity and mortality after surgery. There are evidence-based guidelines that support the use of pulmonary function tests (PFTs) and cardiopulmonary exercise testing (CPET) in the preoperative assessment of patients undergoing lung resection surgery to determine whether patients can tolerate the resection. Spirometry, lung volumes and flow—volume analysis provide information on the respiratory mechanics of the patient while transfer factor and arterial blood gas analysis help to evaluate the ability of lung parenchyma in gas exchange. CPET evaluates the dynamic response of the cardiac and pulmonary function to exercise. The forced expiratory volume at 1 second (FEV_1) and predicted postoperative FEV_1 ($ppoFEV_1$) are useful indicators of postoperative respiratory complications following thoracic surgery. CPET measures VO_{2Max} and can help in the selection patients for lung resection.

Keywords Cardiopulmonary exercise test; lung function tests; preoperative assessment; spirometry; thoracic surgery

Royal College of Anaesthetists CPD matrix: 3G00

Learning objectives

After reading this article, you should be able to discuss:

- when pulmonary function testing should be considered
- the available tests of pulmonary function
- the difference between static and dynamic tests of pulmonary function
- how these tests contribute to the pre operative assessment of patients

Pulmonary function tests are used to evaluate the patients before lung resection surgery. Patient's general clinical state including their co-morbities such as any cardiac or other systemic diseases, anaemia, and nutritional status are important in the preoperative evaluation of these patients. Weight loss greater than 10% and low serum albumin are markers of advanced disease and indicate increased risk during surgery. Pulmonary function tests (PFTs) are used in conjunction with these findings to evaluate the risk of resection and risk of postoperative complications.

Reasons for PFTs before thoracic surgery

The most common problem after thoracic surgery is atelectasis, which reduces lung compliance and functional residual capacity. In addition, lung resection surgery is associated with marked changes in respiratory function, both as a consequence of lung resection and as a result of altered chest wall dynamics due to thoracotomy incision. These changes include significant reductions in maximal expiratory force, vital capacity (VC), forced expiratory volume in 1 second (FEV_1), and peak expiratory flow rate (PEFR). The decrease in VC often exceeds the volume of lung removed during surgery. Patients with lung cancer may also have abnormal pulmonary function prior to surgery, most often due to smoking. These patients are at risk of both immediate perioperative pulmonary complications and long-term disability following curative intent surgery while suboptimal lung resection decreases the survival benefit. PFTs are used to stratify the risk of lung resection and predict the risk of postoperative complications.

To minimize postoperative respiratory complications, medical therapy can be instituted in patients with pre-existing respiratory problems to optimize the pulmonary function before surgery. PFTs help in identifying patients with preexisting respiratory problems and evaluating their response to such optimization therapy. This concept has been expanded into 'preoperative pulmonary rehabilitation' where patients are given a 2-week period of intense breathing exercises including incentive spirometry and regular nebulized bronchodilators. The evidence for this is still limited.

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Tests of pulmonary function

Pulmonary function is measured in a three-legged approach, with tests for respiratory mechanics, lung parenchymal function and cardiorespiratory reserve comprising the three legs of the assessment. There are other tests such as imaging which provide additional information and are used along with the conventional tests in risk stratification and perioperative management of patients for lung resection.

Tests for respiratory mechanics

Spirometry and flow—volume analysis

The most commonly used test to assess suitability for lung resection surgery is spirometry. Spirometry with flow—volume loops assesses the mechanical properties of the respiratory system by measuring expiratory volumes and flow rates. It is a versatile test of pulmonary physiology. The patient breathes through the mouth into the spirometer with nose clipped. At the end of a normal tidal volume expiration, the patient breathes in up to the total lung capacity and performs a forced vital capacity (FVC) manoeuvre and a volume—time curve is recorded (Figure 1). A flow—volume loop is recorded when the patient breathes in, after complete expiration to residual volume, to reach the total lung capacity and forcefully breathes out back to residual volume (Figure 2).

FEV_1 and FVC, which is the largest volume expired from the total lung capacity, are measured from these tests. Results are

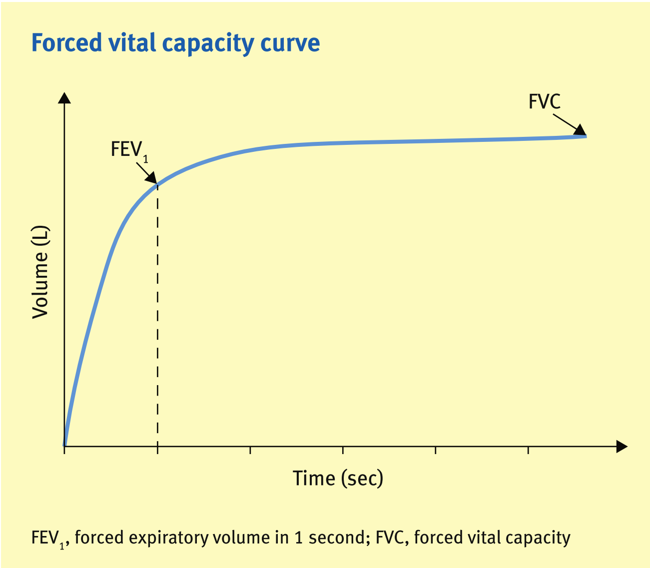

Figure 1

typically reported in both absolute values and as predicted percentages of normal. Normal values vary, depending on gender, race, age and height, and can be used to determine the pattern of lung disease as well as to establish any reversibility with bronchodilators. The results obtained from the volume–time curves are effort dependent and can be underestimated. In normal individuals, the FEV_1 and FVC should be more than 80% of predicted values for their height and weight. These values and the FEV_1/FVC ratio are used to determine the nature of the lung disease. The flow–volume loop is used to measure the flow pattern during inspiration and expiration (Figure 2). Peak expiratory flow and FVC can be derived from the loop. It is also useful to evaluate the nature of lung disease (restrictive or obstructive) and, in addition, presence of any major airway obstruction.

Spirometry and flow–volume analysis are performed whilst the patient is at rest and so they do not reflect the way the whole cardiorespiratory system responds to increasing workload.

Tests for lung parenchymal function

Diffusion capacity of lung

Diffusion capacity of the lung is the ability of the alveolar capillary membrane to transfer gas across it. Diffusion capacity of lung for carbon monoxide (DLCO) is used to assess alveolar membrane efficiency. Carbon monoxide (CO) is 400 times more avid to haemoglobin than oxygen and hence is rapidly taken up by haemoglobin with its transfer limited mainly by diffusion. The patient takes a VC inspiration from the residual volume and inhales a mixture of 0.3% carbon monoxide and 10% helium. The gas mixture exhaled following 10 seconds breath-holding is analysed and DLCO is calculated using a formula. DLCO is the volume of CO transferred across the alveoli per minute per unit alveolar partial pressure and is reduced with increased alveolar membrane thickness as in pulmonary fibrosis. It will also be reduced following pneumonectomy as a result of reduced total alveolar membrane area. DLCO is also expressed in absolute values and in percentage predicted values. The predicted values are reference values generated from a healthy population. The normal values vary depending on age, sex, height, exercise, body position and altitude and it should be interpreted taking these factors into consideration. DLCO is identified as one of the independent predictors of major complications following pneumonectomy.

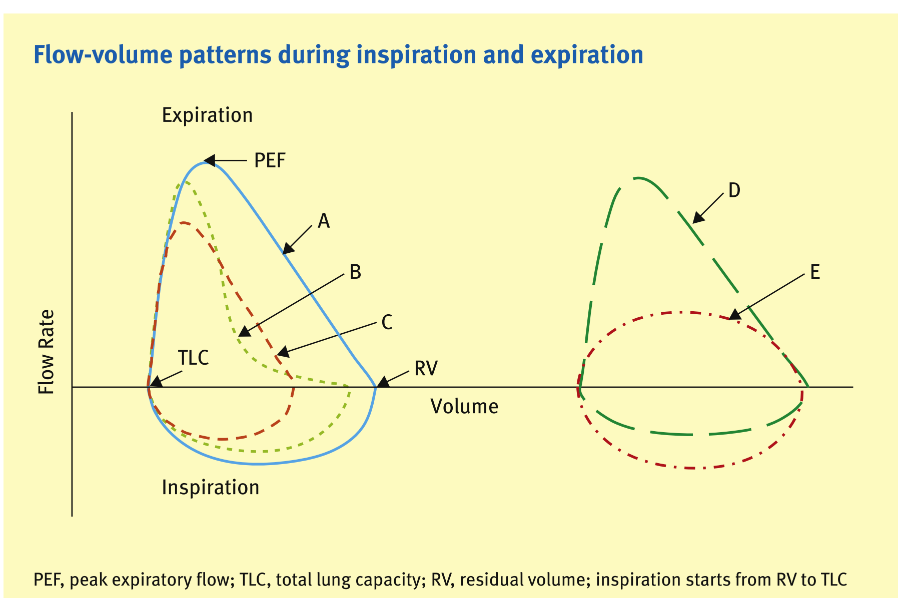

Figure 2 A, normal lung. Normal PEF is achieved during forced expiration. B, obstructive lung pathology. Flow rate is low during expiration and the prolonged expiration causes the typical concave pattern of the waveform. Less PEF is achieved during expiration. C, restrictive lung pathology, lung volumes and PEF are less. D, variable extra thoracic airway obstruction. Flow is normal during expiration and decreased during inspiration. E, variable intrathoracic airway obstruction. Flow is normal during inspiration and decreased during expiration.