LEADING ARTICLE

MEASURING VENTILATORY FUNCTION - THE 'FVC' MANOEUVRE

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Ventilation consists of the movement of air from the atmosphere to terminal lung units. It depends upon the interaction between the capacity of respiratory muscles, the mechanical properties of the chest wall, conducting airways and alveoli. Ventilatory function tests provide complementary and progressively more complex information about the determinants of airflow from the mouth to alveoli.

These tests include measurements of:

A. the visco-elastic (static) properties of the lung and chestwall

B. the strength of those chest wall muscles which drive the respiratory pump

C. the relationships between airflow, lung volumes and driving pressures, and

D. the uniformity of airflow distribution among the alveolar units.

Measurement of flow and/or volume during a maximal forced expiration or the Forced Vital Capacity (FVC) manoeuvre is the most widely used and most useful test of ventilation. The FVC manoeuvre is the first test ordered in the evaluation of pulmonary function and may often be repeated to ensure precision, demonstrate objective improvement after therapy or deterioration with disease. It provides information regarding A, B and C in the list above. The measurements may be expressed graphically either as lung volume against time (the spirogram) or airflow against volume (the flow-volume curve). The ventilatory data which may be derived from the FVC manoeuvre include the Vital Capacity (VC), Forced Expiratory Volume in one second (FEV_1), Peak Expiratory Flow Rate (PEFR) and maximal expiratory flow at the mid-point of the VC ($\dot{V}max50$).

Most spirometers in current use will plot the spirogram, flow-volume curve and compute the various parameters from a single forced expiration. It is a non-invasive and relatively inexpensive test with a favourable cost-benefit ratio. The FVC manoeuvre however requires maximal patient participation - to take a maximal inspiration and then forcibly exhale as rapidly and completely as possible.

While the need for maximal effort may be seen as a disadvantage, the "suboptimal" test may itself be an indicator of underlying disease such as muscle weakness or poor co-operation due to cerebral metastases in patients with lung cancer.

The VC was first recorded by John Hutchinson who invented the modern spirometer nearly 150 years ago (1). The VC may be reduced by diseases affecting the thoracic spine, respiratory muscles, pleura, lungs or airways. Because of this lack of specificity the VC is more useful as a screen test for pulmonary disease. The VC is however particularly sensitive to diseases which limit lung expansion such as parenchymal fibrosis.

One hundred years after Hutchinson, Tiffeneau and colleagues timed the expired volume and described the FEV_1(2). This test measures the volume of air expelled in the first second of forced expiration and may be regarded as an index of how rapidly the lungs can empty. It has a high degree of precision and is the traditional "gold standard" measure of airflow obstruction. The expiratory flow capacity is reduced relative to volume expansion in obstructive disease i.e. the lungs tend to empty more slowly than normal but lung filling is less affected. This results in a relatively greater reduction of FEV_1 than VC, thus a reduced FEV_1/VC ratio is considered the hallmark of airways obstruction.

Diseases which predominantly restrict lung expansion and reduce the VC may leave the lung emptying rate and therefore FEV_1 relatively unaffected. In severe restrictive disease the VC may become so small that it is emptied in less than one second and the FEV_1 / VC ratio equals 1. The FEV_1 will then be equal to the VC and reflect the severity of lung restriction. The FEV_1 is thus a versatile and self adjusting test which can measure either obstructive or restrictive disease (3).

Constitutional factors such as age, sex, body size and ethnic origin plus testing conditions which include posture and time of day may all influence ventilatory function and should be accounted for in the interpretation of results. The article by Duncan et al in this issue of the SMJ reminds us that altered physiological states such as fasting may also affect pulmonary function. They suggested that the observed reduction in PEFR during fasting may be a sign of smaller airway caliber. The lower PEFR could, on the other hand, be due to sub-maximal effort in performing the FVC manoeuvre. If Duncan et al had recorded flow-volume curves in their subjects, it might have been possible to distinguish between the effects of fasting on muscular effort and airway caliber.

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The flow-volume curves provide additional information and permanent copies should be recorded whenever possible during the measurement of FVC. Expiratory flow rates at high lung volumes and in the early portion of the flow-volume curve, which includes the PEFR partly dependent on effort while airflow at lower lung volumes, V̇max50 for example, is determined mainly by intrinsic mechanical properties of the lung (elastic recoil pressure) and airways (cross-sectional area-transmural pressure relations) (5). The expiratory flow at lower lung volumes have been extensively used in recent years to assess airway and lung parenchymal function.

The ratio of physiological dead space to tidal volume (VD/VT) measured by Duncan et al is not a test of forced expiration. The VD/VT is affected by the breathing pattern (the depth and timing of tidal ventilation), volume of conducting airways (anatomic dead space) and the boundary events which occur when atmospheric air meets alveolar gas (6). It is a polyvalent test which is sensitive to changes in both ventilatory and gas-exchange function. Duncan et al only measured a limited number of pulmonary function indices. It would therefore be difficult to comment on the possible causes and clinical significance of the small changes in VD/VT observed by these authors during fasting.

The informed analysis of ventilatory measurements will continue to benefit both the patient who suffers from respiratory disease and the physician who seeks to understand and treat it better. Moreover, ventilatory function tests are the indispensible searchlights which guide the research worker on to those deeper levels where the newer "cutting edge" tools of respiratory cell and molecular biology may be applied.

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