CHAPTER 1: SPIROMETRY AND FLOW–VOLUME CURVES

SPIROMETRY AND FLOW–VOLUME CURVES

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1.1 Subdivisions of lung volume.

Figure 1.1 shows lung volumes and capacities; spirometry can measure the volumes which are shaded. Expiratory effort cannot squeeze all gas out of the lungs; the minimal volume, inaccessible to spirometry, is called residual volume (RV).

At rest, breathing takes place in the upper 50% of TLC, called the inspiratory capacity (IC), although only a fraction of this is used (15–30%) except for sighs and yawns, etc. On exercise, tidal volume (VT) increases (as well as frequency) and increasing amounts of the IRV and ERV (Figure 1.1) are recruited.
In summary:

- VC decreases with ageing (dependent zone airway collapse/closure)
- VC is reduced in obstructive as well as restrictive disease
- VC may be normal in pulmonary vascular disease, and in early emphysema (without bronchitis)

1.2 **Dynamic spirometry (FEV\textsubscript{1}, FVC, PEF)**

The forced expiratory volume in one second (FEV\textsubscript{1}) was introduced by Tiffeneau in 1947 (Yernault, 1993); it has remained a key test ever since. Subjects must inspire quickly to TLC and, *without pausing*, exhale as forcefully and as fast as possible; the “blow” must continue for as long as possible (> 6 s in patients with airflow obstruction), with encouragement from the operator, to obtain the FVC and, thus, the FEV\textsubscript{1}/FVC ratio. The mantra is **F–F–F**: *Full inspiration–Forceful expiration–Full expiration*. Maximum effort is associated with a significant fall in FEV\textsubscript{1} (up to 5%) in about 7% of subjects because of gas compression and a fall in thoracic gas volume caused by high alveolar and pleural pressures (see Figure 1.3 and 1.3.3, p.7-9); nevertheless, **dynamic spirometry should always have maximal effort for consistency**.

![Spirogram](image)

*Figure 1.2* Forced expiratory volume versus time for a normal subject and patients with COPD (obstructive) and lung fibrosis (restrictive). FET is forced expired time. Note for COPD, expired volume continues to increase being 0.3 L greater at 10 s (FVC) versus 6 s (FEV\textsubscript{6}), with a correspondingly greater FEV\textsubscript{1}/FEV\textsubscript{6} (0.4) than FEV\textsubscript{1}/FVC (0.35) ratio.
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Figure 1.3 Maximal expiratory flow plotted against forced expired volume. Curves in A show effect of ageing with a “knee” in young and curvilinearity or “scooping” (not as severe as in COPD) in older subjects. B shows effects of gas compression when volume axis alters from expired volume change to thoracic gas volume (TGV) change; a submaximal effort may go outside the expired volume envelope (see text). C shows typical MEFV curves for the restrictive and obstructive pathologies. D shows the progression of COPD from the early to late stages.

The MEFV curves in normal subjects may show marked individual differences (which are very repeatable) in the first 33% of expired volume (some individuals have a pronounced plateau or “knee” of flow [Figure 1.3A]), but there is generally a linear decrease of flow over the last 66% of the FVC with no concavity or “scooping” (elderly normals may show mild scooping, Figure 1.3.A). Airflow obstruction shows profound curvature (Figure 1.3.C and D). In cases where the FEV₁/VC ratio is borderline,
1.6 Learning Points:

- The vital capacity is reduced in restrictive and obstructive disease.
- In airflow obstruction the FVC underestimates the actual VC.
- The FEV₁/FVC ratio is a good estimate of airflow obstruction, but the ratio declines with age.
- The shape of maximum expiratory (MEFV) and inspiratory (MIFV) flow–volume curves is more informative than the calculation of flow–volume indices.
- Peak expiratory flow does not distinguish obstruction from restriction.
- Choke points in the central intrathoracic airways set maximal expiratory flow, based on their bronchial wall wave speed — a function of their compliance and area, and the gas density.
- Inspiratory flow is determined by the force and speed of muscular contraction; disease of the extrathoracic airway may limit maximum inspiratory flow.

Further Reading

General


Technical


Historical