Title: Spirometry

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I. Measurements of Ventilation – Spirometry

A. Pulmonary Volumes

1. The tidal volume (TV) is the volume of air that is inspired or expired with each normal breath (about 500 milliliters).

2. The inspiratory reserve volume (IRV) is the maximum volume of air that can be inspired with a maximal inspiratory effort *in excess of the normal tidal volume* (about 3000 milliliters).

3. The expiratory reserve volume (ERV) is the maximum volume of air that can be expired *from the resting–end expiratory level by an active expiratory effort* (about 1100 milliliters).

4. The residual volume (RV) is the volume of air that remains in the lungs *after the most forceful expiration* (about 1200 milliliters).

B. Pulmonary Capacities - *include two or more pulmonary volumes*.

1. The vital capacity (VC) is the maximum volume of air that can be expired *from the point of maximum inspiration* (about 4600 milliliters).

VC = IRV + TV + ERV

2. The inspiratory capacity (IC) is the maximum volume of air a person can breathe in *from the resting-end expiratory level* (about 3500 milliliters).

IC = IRV + TV

3. The functional residual capacity (FRC) is the volume of air that remains in the lungs *at the end of normal expiration* (about 2300 milliliters).

FRC = ERV + RV

4. **The total lung capacity (TLC)** is the volume of air contained in the lungs *at the end of maximum inspiration* (about 5800 milliliters).

TLC = IRV + TV + ERV + RV

TLC = VC + RV

TLC = IC + FRC

C. The role of FRC (normal breathing) and RV (depeest breathing) is to act as *a buffer against extreme changes in alveolar oxygen and carbon dioxide partial pressures*.

D. ***Measurement of RV, FRC, and TLC is impossible by a direct method /spirometry/ !***

E. Pulmonary volumes and capacities are affected by physical characteristics, such as sex, age, height and weight, and sporting activity. Its only by comparison with normal values predicted according to physical characteristics, that it is possible to evaluate the results obtained by pulmonary function tests.

F. Pulmonary Function Tests

1. ***The vital capacity test*** **is performed to determine the vital capacity (VC) and it's volume compartments (TV, ERV, and IRV).**

2. ***The forced (expiratory) vital capacity test is used to determine the airway resistance and to detect airway obstruction.*** Several measurements are obtained by the FVC maneuver, such as:

a. The forced (expiratory) vital capacity (FVC).

b. The forced expiratory volume during the first second (FEV_1)

c. FEV_1/FVC [%] ratio.

d. Maximum expiratory flows measured at different levels of lung volume (flow-volume curve):

- Peak expiratory flow (PEF) – the highest rate of airflow during expiration.

- Forced expiratory flow at 25% of FVC (FEF 25).
- Forced expiratory flow at 50% of FVC (FEF 50).
- Forced expiratory flow at 75% of FVC (FEF 75).

3. FEV_1 (FVC test) is additionally referred to VC (VC test) to calculate FEV_1/VC [%] ratio.

G. The spirometer cannot be used in a direct manner to measure the residual volume (RV) or the functional residual capacity (FRC). They can be determined by means of a helium dilution method based on rebreathing from the closed circuit helium apparatus to the point of stabilization of helium concentration. Since the initial volume of the system and both the initial and final concentration of helium is known, the last parameter, which is the final volume of the system, can be calculated. If the test stars at the end of quiet expiration, the final volume of the system is the sum of the volume of the apparatus plus FRC. But if the test begins at the end of the deepest expiration, the final volume of the system is the sum of the volume of the apparatus plus RV.

$$\text{Final volume of the system} = \frac{\text{Initial concentration of helium} \times \text{Initial volume of the system}}{\text{Final concentration of helium}}$$

Determination of the functional residual capacity (FRC) or the residual volume (RV) allows calculating the total lung capacity (TLC).

II. Presentation and Interpretation of Pulmonary Function Tests Obtained by Means of Spirometry. Interpretation Algorithm.

There are two major categories of lung disorders that affect the results obtained by pulmonary function tests: **restrictive changes and obstructive changes**.

1. ***The restrictive changes*** are found in lung and/or chest abnormalities, which cause a decrease in the amount of normally ventilated lung tissue. They include *pleural diseases, alveolar filling processes, interstitial diseases, or may be present because of thoracic cage abnormalities, obesity, or neuromuscular involvement of the respiratory muscles.*

a. ***Results of VC test*****: decreased** all lung volumes and capacities **(↓VC, ↓IRV, ↓TV, ↓ERV)**

b. ***Other changes*** **(calculated): ↓RV, ↓FRC, ↓TLC**

c. ***Results of FVC test*****:**

- **↓FVC, ↓FEV_1, normal or increased FEV_1/F(VC)[%] ratio**
- Flow-volume curve has relatively an unaffected shape, but its overall size appears reduced when compared to normal on the same curve.

2. ***The obstructive changes*** are characterized by increased airway resistance. The most common reason of lower airway obstruction is *asthma* or *COPD - chronic obstructive pulmonary disease, which includes chronic bronchitis and emphysema.*

a. ***Results of VC test and RV calculation*** **depend on how severe is the obstruction:**

- ***Mild obstruction*****: normal VC, normal RV, normal TLC or**
- ***Severe obstruction (air trapping)*****: ↓VC, ↑RV, ↑FRC, ↑TLC** (hyperinflation)

b. ***Results of FVC test*****:**

- **↓FEV_1, ↓ or normal FVC, and decreased FEV_1/F(VC)[%] ratio**
- Airway obstruction decreases mid-range flows (FEF 25-75) and peak expiratory flow (PEF).

The primary indicator of airflow obstruction is reduced FEV_1 and FEV_1/F(VC) percentage.

3. *In restrictive disorders, the vital capacity is always reduced while in obstructive changes VC may be either normal or reduced because of air trapping (severe obstruction).*

4. ***Mixed changes (obstruction and restriction)*** may be present if ***reduced FEV_1 and FEV_1/F(VC)[%] ratio is associated with reduced VC. Then concurrent restriction cannot be excluded.*** *To distinguish between severe but pure obstruction or mixed changes one can determine the total lung capacity (TLC).*

5. Less common *obstruction of upper airway, trachea, or large bronchi* may be suggested by spirometry. It is categorized into *fixed* and *variable* obstruction (where airflow is compromised by dynamic changes in airway diameter).

a. ***Variable obstruction of the intrathoracic airways*** may be caused by tracheomalacia or neoplasm. *In the FVC test, it primarily effects on the expiratory portion of flow-volume loop a*nd could be difficult to distinguish from small to medium sized airway obstruction.

b. ***Variable obstruction of the extrathoracic airways*** may be caused by vocal cords paralysis, thyromegaly, tracheomalacia, or neoplasm. *In the FVC test, it primarily effects on the inspiratory portion of flow-volume loop producing flattening of the inspiratory curve*.

c. The reasons of fixed obstruction, either extrathoracic or intrathoracic, include tracheal stenosis, presence of foreign body, or neoplasm. *Fixed obstruction effects on both the inspiratory and expiratory portions of the flow-volume loop producing a squared loop.*