RESPIRATORY PHYSIOLOGY

1. Definitions
Breathing is a vital function of the human body, running continuously and cyclically and is
designed to provide bidirectional exchange of gases between the body and the atmospheric air.
Through breathing O$_2$ is brought from the external environment and transported to the cells, while
CO$_2$ which results from cellular metabolism is eliminated into the atmosphere.
Breathing is comprised of two components:
- External respiration, which is the exchange of gases between the lungs and the atmosphere;
- Internal or tissue respiration, which refers to the use of oxygen in oxidation-reduction reactions
  at the cellular level.
External respiration involves three processes: ventilation, perfusion and diffusion. Of these
processes, in these practical activities we will study ventilation.

2. Brief overview of respiratory anatomy
The morphological components of the respiratory system are the airways (upper and lower) and
lung parenchyma consisting of pulmonary acini. The respiratory airways ensure the transport of
gases and improve the quality of the inspired air, while the pulmonary acini are involved in
gaseous exchange.
The upper respiratory airways are comprised of the nasal segment, oral cavity and partially the
pharynx until the glottic opening and the lower airways are: the larynx, the trachea, the bronchi
and their ramifications.
The pulmonary acinus represents the morhfoo-functional unit of the lung, which, from an anatomic
point of view, is the region that corresponds to a single terminal bronchiole, from which 2-3
generations of respiratory bronchioles derive. The terminal bronchiole along with the respiratory
bronchioles and their ramifications: alveolar ducts, alveolar sacs and pulmonary alveoli form the
pulmonary acinus. All pulmonary acini form the lung parenchyma, which ensures gaseous
exchanges.

Note! For a better understanding of the physiology of the respiratory system, you are invited to
read further on the anatomy of this physiological system from any anatomy book.

3. Mechanics of pulmonary ventilation
Pulmonary ventilation is comprised of all the mechanical processes that ensure the exchange of
gas between the atmosphere and the lungs. Through ventilation, oxygen rich air is introduced into
the pulmonary alveoli during inspiration and carbon dioxide rich air is eliminated from the lungs
into the atmosphere during expiration.
Gaseous exchanges between the atmosphere and the lungs takes place due to differences in
pressure (pressure gradient) between the two environments. These differences are due to
variations in lung volume, which occur because the lungs follow passively the movements of the
thoracic wall. The resulting pressure gradient will cause a movement of air from high pressure
environment to low pressure environment.
The two phases of ventilation, inspiration and expiration succeed each other rhythmically with a
frequency of 12-18 cycles / minute (respiratory rate). Respiratory rate is the number of respiratory
cycles (inspiration and expiration) per minute and varies depending on:
- Age: Newborn = 30-45 c / min; children = 20 to 30 c / min, adults = 12 to 18 c / min;
- Sex: women have a higher rate than men: 15 to 18 c / min;
- Physical activity: 30 - 40 c / min in intense exercise.
A respiration rate higher than the normal limit is called **tachypnea** and lower rate is called **bradypnea**.

The thoracic cavity is a structure that must be rigid enough to protect the vital organs it contains and to provide an insertion surface for the muscles present at this level. Pulmonary ventilation, on the other hand, requires a flexible chest that can function as a "windbag" (as in a bagpipe) during the respiratory cycle. Ribs and costal cartilages are flexible enough to be mobilized and extended as a result of the contraction force provided by inspiratory muscles and to return passively to their initial state, when muscles relax and the traction force ceases. Lungs, although easily distensible and elastic structures, they do not possess muscular elements and cannot initiate on their own volume changes characteristic to respiratory phases. Therefore they will follow passively the movements of the chest, to which they are connected through the pleural system comprising of the parietal pleura (adhering closely to the chest wall) and the visceral pleura (which surrounds the lungs).

During inspiration, atmospheric air enters the lungs, because the pressure of atmospheric gas is higher than the intrapulmonary or intra-alveolar pressure. As atmospheric pressure is usually constant (760 mmHg), for gas exchanges to occur, the only pressure that can vary is the intrapulmonary one.

A pressure lower than atmospheric pressure is called **subatmospheric** or **infraatmospheric** or improperly called "**negative pressure**". The term negative pressure does not define a real negative pressure, but the decrease by 3-4 mmHg of pressure in the lungs compared to that of the atmosphere. During inspiration, while resting, intrapulmonary pressure decreases by approx. 3 mmHg compared to atmospheric pressure. Exhalation occurs when intrapulmonary pressure is higher than atmospheric pressure. During expiration, while resting, intrapulmonary pressure increases by at least + 3 mmHg above atmospheric pressure.

**Inspiration** is triggered by stimuli generated in the inspiratory center of the bulb (medulla oblongata), which travel to the motor neurons of the anterior spinal horns. Through the spinal nerves the impulses contract the inspiratory muscles.

During **resting inspiration** the **diaphragm** and **external intercostal muscles** contract. The diaphragm is the main inspiratory muscle. It separates the chest cavity from the abdominal cavity and at rest is curved, with its convexity oriented towards the chest cavity. By contraction, the diaphragm flattens and lowers by approx. 1.5 to 2 cm during resting inspiration and 7-8 cm in forced inspiration. By lowering, the diaphragm increases the longitudinal diameter of the thoracic cavity, but also the transverse diameter at its base. The volume increase resulted by contracting this muscle allow a quantity of air to be introduced into the lungs, quantity known as **current volume** (tidal volume (VT)). Complete paralysis of this muscle makes breathing impossible.

The contraction of the external intercostal muscles, cause the ribs to horizontalize and rotate, while projecting the sternum anteriorly. As a result the anterior-posterior and transverse diameters of the thoracic cavity increase.

The increase of thoraco-pulmonary volume decreases pulmonary pressure to a value of 756-757 mmHg, lower that air pressure by approx. 3 to 4 mm Hg. As a consequence of these changes a volume of air enters the lungs, until the two pressures equalize.

The volume of air that enters or leaves the lungs during resting or relaxed breathing is called **CURRENT VOLUME** or **TIDAL VOLUME** - VT

In **forced inspiration**, besides the diaphragm and external intercostal muscles, the accessory muscles also contract: the scalene muscles, the pectoralis muscles, the serratus muscles, the sternocleidomastoid muscles, the trapezius muscles.

Contractions of the muscles belonging to the nasal fins, the soft palate, the tongue, facilitate the passage of air through the upper airways.
The accessory inspiratory muscles offer an additional lift of the upper chest, increasing thoraco-pulmonary volume and further lowering the pressure. Through these modifications, a supplementary volume of air is introduced = INSPIRATORY RESERVE VOLUME = VIR.

Expiration
Resting expiration is a passive phase (without power consumption), in contrast to inspiration that takes place actively through muscle contraction and energy consumption.Expiration occurs when the thoraco-pulmonary structures return to the original position after the deforming force has terminated. Thoraco-pulmonary elasticity plays an important role. As a result, the lung decrease in volume and intrapulmonary pressure increases, making it higher than atmospheric pressure by 3-4 mm Hg (763-764 mm Hg). This results in the elimination of a volume of air rich in CO\textsubscript{2} from the lungs into the atmosphere.

Forced expiration is an active phase, which takes place due to expiratory muscles contraction, muscles represented mainly by the abdominal muscles and internal intercostal muscles. The contraction of the abdominal muscles increases intra-abdominal pressure, which in turn increases the convexity of the diaphragm and further reduces thoracic and pulmonary volume. Following further increase in intrapulmonary pressure, an additional amount of air will be expired - EXPIRATORY RESERVE VOLUME - VER.

Figure1. Mechanics of pulmonary ventilation. Source: Stuart Ira Fox. HUMAN PHYSIOLOGY, 12\textsuperscript{th} ed.

4. Pulmonary perfusion
Pulmonary perfusion is provided by two types of circulation:
- Functional - represented by the pulmonary circulation or minor circulation;
- Nutrition - provided by the bronchial arteries and veins.

- **Functional pulmonary circulation** starts at the right ventricle with the pulmonary artery and ends in the left atrium with the 4 pulmonary veins. The pulmonary artery originates in the right ventricle and afterwards branches into branches into two pulmonary arteries, one for each lung. Each pulmonary artery (right or left) continues to branch giving birth to capillaries. Capillaries form a network around the pulmonary alveoli, where they participate in forming the alveolar-capillary barrier (called the respiratory membrane). At this level gaseous exchanges occur. This network then forms veins that carry oxygenated blood. Veins convergence into larger and larger branches and eventually leave the lungs as two pulmonary veins. The four pulmonary veins, two right and two left, drain into the left atrium, thereby closing the minor pulmonary circulation.

  - The importance of pulmonary circulation:
    - Ensures blood oxygenation and CO$_2$ removal;
    - It is a filter for emboli;
    - At this level a number of active substances are produced (prostaglandins, angiotensin II);
    - Constitutes a reservoir of blood for the left ventricle.

- **Nutritional pulmonary circulation** is provided by the bronchial arteries (from the thoracic aorta) and internal thoracic arteries. The blood irrigates the walls of the bronchial tree and the supportive lung tissue (stroma). Bronchial arteries only reach up to the respiratory bronchioles, where they form a capillary network, a starting point for the bronchial veins. The blood from the nutritional pulmonary circulation drains, through the bronchial veins, into the pulmonary veins, reducing the O$_2$ saturation in the minor blood circulation.

5. Diffusion
Diffusion is the process through which pulmonary gas pass between the alveolar gas environment and the pulmonary capillary blood, according to the concentration gradient (from high to low concentration). This is influenced by several factors:

- Alveolar-hematic barrier qualities;
- Pressure gradient;
- Gas diffusion constant;
- The area of the exchange surface;
- Contact time between the two environments.

The alveolar-hematic barrier consists of the pulmonary surfactant layer lining the alveoli, the alveolar epithelium, the alveolar basement membrane, interstitial fluid, capillary basement membrane, capillary endothelial cells, the layer of plasma, red blood cell membrane.

6. Exploration of respiratory system
The respiratory system can be explored through a variety of investigations, each offering more or less detailed information regarding the structure or function of this vital bodily system. For example, imaging exploration: chest X-ray and mediastinal computer tomography (CT) provides a great deal of information about the anatomy of the lungs, which helps diagnose a large number of diseases (pneumonia, pleural effusion, pulmonary tuberculosis, pulmonary fibrosis, tumor pathology etc.). Other imaging investigations such as bronchography or scintigraphy offer more information regarding the aspect and structure of the bronchial tree, or changes in caliber and discontinuity of bronchial lumen due to a tumoral formation (bronchography) or regarding pulmonary perfusion and gas distribution in the lungs (scintigraphy).
Respiratory function tests reveal information on how good the lungs perform their function by measuring pulmonary volumes, capacities and flow rates. The discipline of physiology deals with the functional aspect of respiratory exploration, while another disciplines will complete this chapter of exploration, with specific investigations.

6.1. The Pneumogram

- **The pneumogram** is a graphic recording respiratory movements with the aid of a sensor (transducer) or through the electrical impedance method.

- **The pneumogram** is obtained by registering respiratory movements and consists of an upward slope representing inspiration and a downward slope representing expiration. The downhill section reveals a faster initial portion representing the return of the chest wall to its resting position and a second slower portion representing lung retraction. The ratio of the length of the slope during inspiration to that of the expiration is 1/1.2 - 1/2, with inspiration generally lasting 1s and expiration 2s. With the aid of the pneumogram we can analyze: respiratory frequency, amplitude and rate and the variations that occur in different physiological situations: exercise, sleep, altitude adaptation etc. or pathological situations: sleep apnea, monitoring critical patients in ICU (Intensive care unit) wards.

![Normal Pneumogram](http://www.biyosoft.com/ASP/ECG_dosyalar/rhythm.asp)

6.2. Ventilatory function tests consist of determining the volume of gas in the lungs by measuring pulmonary volumes, capacities and flow rates.

- These measurements are made with a machine called a closed circuit spirograph (breathing in and out of the machine). The method is called spirography and the graph obtained - spirogram.

- the spirogram or closed circuit spirometer is a device in which the subject breathes through a mouthpiece. Breathed air is trapped in a plastic bell-shaped chamber which floats in the water. The bell-shaped chamber moves up when the subject exhales and down when the subject inhales. Bell movements are transmitted to a writing pen that draws a graph, on which inhaled and exhaled volumes are recorded as a function of time.
• **Clinical significance** of respiratory function tests. These tests help doctors:
  o determine the degree of impairment of ventilatory function in various diseases that reduce lung parenchyma (restrictive syndromes) or obstructs bronchial pathways (obstructive syndromes);
  o diagnose certain pulmonary diseases such as asthma or chronic obstructive pulmonary disease (COPD);
  o to assess a person's ventilatory function before surgery;
  o to monitor respiratory function of a person who is regularly exposed to noxious environments such as asbestos, dust, silica, which can affect the lungs;
  o to determine treatment efficiency in different lung diseases.

• Measurements are performed in morning after overnight fasting (a full stomach limits peak expiration) and after a period of at least 2 hours without smoking.

• The following patients do **not** undergo respiratory tests:
  o Patients with chest pain or those that have suffered an acute myocardial infarction (AMI);
  o Patients that have recently underwent eye, chest or abdominal surgery or those that have a history of pneumothorax;
  o Patients with elevated blood pressure;
  o Patients with altered general status.

• **How to make the recording**
  o we explain to the subject the maneuvers that will be performed;
  o a nose clip nose is applied on the subject (to prevent breathing through the nose) and the mouthpiece of the spirometer is placed in the mouth of the subject;
  o the subject is asked to breathe normally for one minute; this graph allows us to calculate the tidal volume (VT), respiratory rate and resting ventilation flow rates;
  o the subjects is required to execute a maximal inspiration followed by an exhale as slowly and complete as possible; thus registering the vital capacity (VC)
  o the subject is then asked to breathe normally for 15 seconds;
  o in order to measure the forced expiratory volume in one second (FEV1) a maximal inspiration is required, followed by a 2 seconds apnea and finally, a fast maximal expiration.
  o three such determinations are performed and the highest vital capacity and FEV1 values are used.

• Volumes, capacities and flow rates are **calculated** following instructions on the spirogram regarding the correlation between height (amplitude graph) and volume. For example, a
small square corresponds to 50 cm$^3$ or 50 ml, between two medium thickness there are 200 cm$^3$ and between two thick lines there are 1000 cm$^3$ (1 liter).

- the results are corrected with correction factors for various volumes and flow rates. The correction factors are: BTPS and STPD.
  - BTPS correction factor is used for all volumes and flows, except O$_2$ consumption; it brings the gas to body temperature, pressure and gas saturated with water vapor.
  - STPD is used for O$_2$ consumption; it brings O$_2$ to standard temperature (0°C), 1 atm pressure and dry gas.
  - modern spirometers automatically correct these volumes in terms of temperature, pressure and water vapor saturation;
  - the results obtained are the **actual or real results** for that patient.

*The results are expressed* in cm$^3$ (ml) or liters for volumes and capacities and in cm$^3$ or liters / unit of time for flow rates (cm$^3$/second for FEV1, cm$^3$ or liters/minute for resting ventilation, maximal ventilation, oxygen consumption).

**Comparison to ideal values.** Due to wide variability of ventilation parameters from one individual to the other, real values are expressed as a percentage of ideal or predicted values for the subject. The ideal value is a theoretical value, calculated using regression formulas, depending on height, sex, age, weight, race. Regression formulas derived from regression curves are based on data obtained from healthy, non-smoking and without clinical or laboratory signs of pulmonary disease. Ideal factors are frequently calculated using CECA factors (European Coal and Steel Commission).

- Using spirometers recorded during practical activities:
  - you will calculate: respiratory rates, volumes, capacities and actual flow rates;
  - you will compare the results to ideal values;
  - you will interpret deviations from ideal values;
  - you will classify the pathological results in restrictive or obstructive syndromes.

Table no. 1 contains parameters recorded on a spirogram, with definitions and comments.

### 6.3. Bronchomotricity tests.

In clinical environment, the spirogram can be recorded after administration of substances that influence bronchomotricity, causing bronchoconstriction or bronchodilation. Those substances are aerosols and the primarily measured parameter is FEV1.

- **Bronchoconstriction tests.** Cause spasms of the smooth bronchial wall muscles, obstructing the bronchi, similar to the parasympathetic nervous system.
  - Substances that mimic the effect of parasympathetic nervous system are used - acetylcholine, histamine, methacholine or various allergens;
  - The substance is administered to asymptomatic individuals who are suspected to have a history of bronchial asthma;
  - the test is significant if FEV1 decreases by more than 15-20% compared to the value obtained from the first recordings.

- **Bronchodilation tests.** Cause bronchial smooth muscle relaxation, acting similar to mediators of the sympathetic nervous system.
  - fast-acting beta-adrenergic drugs are administered or parasympatholytics are inhaled;
  - performed for patients with known obstructive syndrome, either for diagnosis (highlighting the spastic origin of the obstruction) or therapy (to test drug efficacy);
the test is significant if FEV1 increase by more than 10 to 15% of the value obtained from the first recordings.
### Table no.1. Parameters determined through closed circuit spirometry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abbreviation</th>
<th>Reference values</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VOLUME</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current volume/ Tidal volume</td>
<td>VT VT</td>
<td>500-800 ml greater than or equal to 12% of VC</td>
<td></td>
</tr>
<tr>
<td>Expiratory reserve volume</td>
<td>VER ERV</td>
<td>800-1500 ml greater than or equal to 22% of VC</td>
<td><em>Decreases in obstructive syndrome</em></td>
</tr>
<tr>
<td>Inspiratory reserve volume</td>
<td>VIR IRV</td>
<td>1800-2600 ml greater than or equal to 55% of VC</td>
<td><em>Decreases in restrictive syndrome</em></td>
</tr>
</tbody>
</table>
| Residual volume                                | VR RV        | 1200-1800 ml greater than or equal to 25% of TLC      | RV cannot be eliminated from the lungs in a living subject. It is determined through:  
- Calculations: RV = FRC - ERV;  
- The Helium dilution method with a single open circuit respiration. *Increases in obstructive syndrome* |
| **CAPACITIES**                                  |              |                                                       |                                                   |
| Vital capacity                                 | CV VC        | 3500-5000 ml ideal value for men: $I^3 \times F_{CECA}$  
ideal value for women: 80% of $I^3 \times F_{CECA}$ | VC can be determined through calculations using the spirogram: VC = VT + IRV + ERV or pneumotachography. CV varies according to age, sex, constitution, physical training status. CV increases until 25 years of age, is stationary in adulthood and begins to decrease with age when RV increases. *Decreases in restrictive syndrome*. |
<p>| Inspiratory capacity                           | CI IC        | Calculated using the spirogram as the sum of VT + IRV. <em>Decreases in restrictive syndrome</em>. |
| Functional residual capacity                   | CRF FRC      | FRC represents the volume of gas in which inhaled air enters, mixes and dilutes before it enters the blood. |</p>
<table>
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</table>
| **Observations**                  |              |                                                                           |                  | FRC is determined through: - Helium dilution method  
- plethysmography method (body plethysmography)                                               |
| Total pulmonary capacity          | CPT TLC      | The volume of air contained in the lungs at the end of a forced inspiration (maximum inspiratory position). | 5500 - 7000 ml   | TLC is determined through:  
- calculations using the spirogram: TLC = VC + RV or CPT = IC + FRC  
- Helium dilution method, with a single open circuit respiration.  
**Decreases in restrictive syndrome.**                                                  |
| **FLOW RATES**                    |              | **Evaluate the dynamic performance of the respiratory system**           |                  |                                                                                               |
| Forced expiratory volume in 1 second | VEMS FEV1   | Volume of gas exhaled from the lungs in the first second of a fast and maximum expiration, performed after a forced inspiration. It can be measured also at 0.5 sec (FEV0.5) 2 sec (FEV2) 3 sec (FEV3). | 2800-4000 ml greater than or equal to 80% of VC  
**Ideal value** for men: $l^3 \times F_{CECA}$  
**Ideal value** for women: 80% of $l^3 \times F_{CECA}$  
It is also expressed as a percentage of VC (Tiffeneau index or bronchial permeability index BPI).  
$VEMS/CV \times 100$ should be greater than 80%  
This index decreases with age and obstructive diseases. Determining FEV at 2s, 3s (when lungs work with small volumes and when the contribution of the elastic recoil and peripheral resistance is important) may show significant changes even in young people. |                                                                                               |
| Oxygen Consumption                | VO₂ VO₂     | Volume of oxygen retained by the body in one minute while resting         | 200 - 250 ml/min | Increases in maximum effort approx. 20 times                                                   |
| Resting ventilation (Resting respiration rate) | V rep      | Volume of air ventilated by the lungs in one minute while resting         | 6-8 L/min  
**Ideal value:**  
Body surface area x 3.6 (M)  
3.2 (F)  
Real value calculation: VT x respiratory rate |                                                                                               |
| Maximum ventilation               | V max        | Volume of air ventilated by the lungs in one minute during maximum effort | 120 - 150 L/min | Calculation  
Ideal value= ideal VC x 24  
Real value=  
real VEMS x 30                                                                 |                                                                                               |
Reference values include limits generally accepted as normal for a large population group. However, it is possible for a male person, for example, with a height of 1.98 m, with real values between the reference limits, to be outside the normal interval when compared to his ideal values. In fact, the reference values are mostly for guidance in pulmonary function exploration. The population group, that has these values, comprises of a heterogeneous mix of individuals: women, men, young, old, tall, short, overweight, thin etc.

- **Pathological changes of respiratory parameters**
- In **obstructive** syndrome (asthma, chronic bronchitis) = obstructive dysfunction
  - **DECREASE**: FEV1, BPI, ERV, PEFR, Vmax, VC because of ERV decreasing.
  - **INCREASE**: RV, TLC, FRC.
- In **restrictive** syndrome (pulmonary fibrosis, pulmonary tuberculosis, pleurisy, paralysis of the diaphragm etc) = restrictive dysfunction.
  - **DECREASE**: IRV, VC because of IRV decreasing, TLC, Vmax, PEFR normal or decreased, ERV normal or decreased, FEV1 normal or decreased.
  - **NORMAL OR INCREASE**: BPI in parenchimal restrictive disfunction, RV.

### 6.4. Recording maximum instantaneous ventilation flow rates
- uses a flow-volume curve determined using spirometers fitted with a flow transducer, devices called pneumotachographes;
- the recording is made during a maximum forces respiratory cycle: maximum inspiration - as fast as possible, maximum exhalation - as fast as possible
- flow-volume curve - allows a graphical analysis of the airflow generated depending on the volume of air mobilized;
- **instantaneous peak expiratory flow rate (PEFR)**
  - is the highest flow rate value reached during forced exhalation;
  - an increase in PEFR by more than 35% compared to reference values occurs in obstructive syndrome, but also in restrictive;
  - PEFR can be monitored using "peak flowmeters" allowing for self-monitoring of asthma;
  - daily recording and graphs with the determined values allow the doctor to check if the asthma is well controlled or not.
1. By consulting a medical dictionary, the "Physiology of the respiratory system" course, recommended bibliography materials and other reliable sources, you are asked to define in your dictionary notebook the following terms: apnea, self-monitoring, tachypnea, slow
breathing, correction factor, ratio, percentage, monitoring, real value, ideal value, predicted value, bronhomotricity, bronchoconstriction, bronchodilation, asthma, restrictive syndrome, obstructive syndrome, inhalants, parasympathomimetic, parasympatholytic, sympathomimetic, sympatholytic or other terms found in this material that you are not familiar with.

2. List in writing mediators with bronchoconstrictive action. Specify which autonomic system they belong to?
3. List in writing mediators with bronchodilating action. Specify which autonomic system they belong to?

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Optional reading

**Pneumotachography** is a modern method of exploring pulmonary ventilation, based on mechanical and electronic means, recording data mainly related to flowmetry (flow rates), expiratory and inspiratory flow-volume curves or calculating FVC (forced VC), FIVC (forced inspiratory VC), SVC (slow VC).

- **FVC** - maximum volume of air inspired and then rapidly and completely expired.
- **FIVC** - maximum volume of air expired, after a fast and complete inspiration.
- **SVC** - volume completely and slowly exhaled, after a complete inspiration.
- **FEV1** - Forced expiratory volume in the first second of a forced expiration conducted after a forced inspiration (FEV1). Testing can be done at 0.5s, 2s, 3s.
- **FEV1 / VC** ratio, Tiffeneau or bronchial permeability index. Physiological values are equal to or greater than 80% and decrease with age.
- **FEF** = forced expiratory flow at 25%, 50%, 75%, 75% to 85% of CV
- **FEF 25-75%** is the average forced expiratory flow between 25% and 75% of CV equal to the ratio between the forced expiratory volume, after the first quarter of CV is exhaled and until the third quarter of CV is exhaled and the corresponding time.
- **PEF (peak expiratory flow)**, representing the highest value of forced expiratory airflow after a maximum inspiration. The maximum flow, which is maintained 10 ms, is registered. Normal values of this parameter: 9.5 - 10 l/s in men and 7-8 l/s in women being calculated using the flow-volume curve.
- **MEF** = instantaneous maximal expiratory flow at 25%, 50%, 60%, 75% of CV, representing forced expiratory flow rate when 25%, 50%, 60%, 75% of CV is left in the lungs. It can be calculated using the flow-volume curve.
- **MEF 25% = FEF 75%**, **MEF 50% = FEF 50%** etc. These parameters can also be calculated in forced inspiration (MIF, FIF).