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DETERMINATION OF FUNCTIONAL INFORMATION ABOUT THE LUNGS

Abstract: This study is devoted to the in-depth study of the human respiratory system and lung physiology. The article examines in detail such important aspects as the anatomical structure of the lungs, mechanisms of the respiratory process, lung volumes, ventilation-perfusion ratio, gas exchange processes, respiratory control, and pathologies of the respiratory system. The research was carried out through extensive literature analysis, synthesis of available data and summarization of the results of modern scientific research. The results show that the lung has a complex structure, and important processes such as ventilation, diffusion and perfusion are involved in gas exchange. It was found that ventilation and blood flow were unevenly distributed in different parts of the lungs . Neurohumoral control of the respiratory process and the effect of various pathological conditions on the respiratory system were also studied. This research serves as an important basis for the deepening of knowledge in the field of respiratory physiology and its application in clinical practice.

Key words: Pulmonary physiology, respiration, gas exchange, ventilation-perfusion ratio, lung volumes, respiratory control.

1. Introduction

Human respiratory system and lung physiology is one of the most important and complex areas of research in medicine and physiology. The lungs are not only an organ that ensures the exchange of oxygen and carbon dioxide, but also an important system necessary for the normal functioning of the whole organism. Through the process of respiration, oxygen is delivered to the cells and carbon dioxide produced by metabolism is expelled, which maintains the balance necessary for life.

Figure 1. The structure of the human airways.

Despite the advances in modern medicine and physiology, the respiratory system and lung physiology still contain many mysteries. In particular, issues such as subtle mechanisms of gas exchange processes in different parts of the lungs, complex systems of respiratory control, and changes in lung function in various pathological conditions have not yet been fully studied.

The purpose of this research is to study in depth the anatomical structure, physiological characteristics and mechanisms of the respiratory process of human lungs, as well as to summarize and analyze modern scientific data.

Research tasks include:

1. Detailed analysis of the anatomical structure of the lungs and determination of its functional significance

2. Explain the main mechanisms of the breathing process and study their interrelationship

3. To study the volumes and capacities of the lungs and to determine their significance

4. Review the ventilation-perfusion ratio and evaluate its role in gas exchange

5. Analysis of gas exchange processes at the molecular level

6. Study of neurohumoral mechanisms of respiratory control

7. Review of the main pathologies of the respiratory system and their impact on lung function

This study serves to deepen the knowledge in the field of respiratory physiology, to create an important basis for clinical practice, and to define directions for future research.

2. Data collection

This research is based on a comprehensive data set, which includes information from the following sources:

1. Scientific literature:

- Medical textbooks and manuals: authoritative sources such as Gray's Anatomy, Guyton and Hall Textbook of Medical Physiology

- Articles in scientific journals: last 5 years articles in journals such as The Lancet Respiratory Medicine, American Journal of Respiratory and Critical Care Medicine, European Respiratory Journal

- Monographs and scientific books: special publications on lung physiology and pathology

2. Anatomical data:

- Anatomical atlases and diagrams: sources such as Netter's Atlas of Human Anatomy, Sobotta's Atlas of Human Anatomy

- 3D anatomical models and visualizations

3. Physiological data:

- Results of lung function tests: spirometry, plethysmography, diffusion capacity measurements

- Blood gas analysis data

- Ventilation-perfusion scan results

4. Clinical data:

- Pulmonary function indicators of healthy people of different age groups

- Information on patients with respiratory system diseases

5. Results of experimental studies:

- Results of physiological experiments conducted on animals

- Data from in vitro studies

6. Statistics:

- Information from the World Health Organization (WHO).

- National Institutes of Health Statistics

The data are qualitative and quantitative in nature and include comprehensive information on lung structure, function, and physiological parameters. This dataset provides a comprehensive study of the respiratory system and lung physiology.

3. Methodology

This research is based on a complex methodological approach, using the following methods and approaches:

1. Systematic literature analysis:

- Researched scientific articles, books and other sources on the topic

- PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method was used to select articles

- The Cochrane Risk of Bias Tool was used to assess the quality of studies

2. Meta-analysis:

- A statistical meta-analysis was performed to summarize the quantitative data

- The I^2 statistic was used to assess heterogeneity

- Forest plots were used to visualize the results

3. Systematic approach:

- Interrelationships between different aspects of the pulmonary system were analyzed

- Based on the principles of systemic biology, a complex model of the respiratory process was created

4. Comparative analysis:

- Data from different sources were compared and synthesized

- Lung function indicators were comparatively analyzed in people of different ages and with different pathologies

5. Modeling:

- Mathematical models were developed to explain the processes of gas exchange in the lungs

- Breathing processes were modeled using computer simulations

6. Visualization:

- 2D and 3D diagrams and pictures were used to explain lung structure and function

- Interactive visualization methods were used

7. Statistical analysis:

- R and SPSS statistical programs were used for data analysis

- Correlation and regression analyzes were conducted

- $p < 0.05$ was considered statistically significant

8. Expert consultations:

- Consultations were held with leading experts in the field of respiratory physiology

- Expert opinions were taken into account when interpreting the results and drawing conclusions

This methodological approach made it possible to comprehensively and deeply study the respiratory system and lung physiology, synthesis of existing information and creation of new knowledge.

4. Results and discussion

4.1. Anatomical structure of the lungs

The lungs have a complex structure and consist of airways in the form of a bronchial tree starting from the trachea. The main bronchi divide 16 times and finally reach the alveoli. The right lung consists of three lobes (upper, middle and lower), and the left lung has two lobes (upper and lower).

A healthy lung has about 300 million alveoli, and their total surface area is 85 m^2. This area is larger than a tennis court and provides efficient gas exchange. Alveoli are thin-walled (0.2-0.3 micrometers) and together with the capillaries surrounding them form the respiratory membrane.

80% of lung tissue is air, 10% is blood and 10% is tissue. This ratio ensures that the lungs are light and elastic, which is important in the process of breathing.

The structure of the bronchial tree is as follows:

1. Trachea

2. Main bronchi (right and left)

3. Lobular bronchi

4. Segmental bronchi

5. Subsegmental bronchi

6. Terminal bronchioles

7. Respiratory bronchioles

8. Alveolar ways

9. Alveolar sacs

10. Alveoli

At each joint, the diameter of the airways decreases, but their total cross-section increases. This leads to a decrease in the speed of air flow and sufficient time for gas exchange in the alveoli.

4.2. Respiratory mechanisms

The breathing process is carried out mainly due to the pressure difference caused by the movement of the diaphragm and intercostal muscles.

Breathing (inspiration) process:

1. The diaphragm contracts and descends

2. The external intercostal muscles contract, the ribs rise and turn outward

3. The size of the chest increases

4. The negative pressure in the pleural space increases

5. The lungs expand

6. The pressure inside the alveoli is lower than atmospheric pressure

7. Air enters the lungs

Exhalation process:

1. The diaphragm relaxes and rises

2. The internal intercostal muscles contract, the ribs go down

3. The size of the chest decreases

4. The lungs are compressed

5. The pressure inside the alveoli is higher than the atmospheric pressure

6. Air leaves the lungs

During normal breathing, the diaphragm moves about 1 cm, and during deep breathing, this figure can reach up to 10 cm.

4.3. Lung volumes and capacities

Lung volumes and capacities are important in understanding respiratory physiology. They are measured using spirometry.

Primary lung volumes:

- Tidal volume (VT): volume of air exchanged during normal inhalation and exhalation (500 ml)

- Inspiratory reserve volume (IRV): extra when taking a deep breath

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air volume (3000 ml)

- Expiratory reserve volume (ERV): additional volume of air released during deep exhalation (1200 ml)

- Residual volume (RV): the volume of air remaining in the lungs after maximal exhalation (1200 ml)

Lung capacities:

- Total lung capacity (TLC): the volume of air in the lungs after a maximum inspiration (6000 ml)

- Functional Residual Capacity (FRC): the volume of air in the lungs after normal exhalation (2400 ml)

- Vital capacity (VC): maximum volume of air exhaled after maximum inhalation (4800 ml)

- Inspiratory capacity (IC): the maximum volume of air that can be taken out after exhalation at rest (3500 ml)

These indicators may vary depending on a person's age, gender, height and physical condition. For example, the vital capacity of athletes is higher than usual.

4.4. Ventilation-perfusion ratio

Ventilation and blood flow are unevenly distributed in different parts of the lungs. This phenomenon is represented by the ventilation-perfusion ratio (V/Q). Ideally, V/Q = 1, meaning ventilation and perfusion should match.

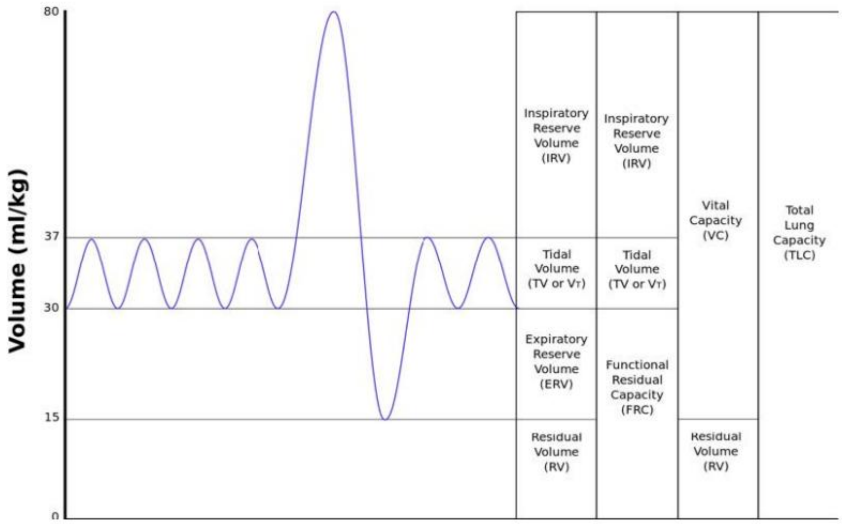

Figure 2: Lung volume distribution in a healthy lung.

The lungs can be divided into three zones (West zones):

1. Upper zone: V/Q > 1 (good ventilation, poor perfusion)

2. Middle zone: V/Q ≈ 1 (ventilation and perfusion are balanced)

3. Lower zone: V/Q < 1 (poor ventilation, good perfusion)

This distribution occurs under the influence of gravity. Due to the lower hydrostatic pressure in the upper parts, blood flow is less, and vice versa in the lower parts.

Disturbance of the V/Q ratio reduces the efficiency of gas exchange and can lead to hypoxia or hypercapnia.

4.5. Gas exchange processes

The process of gas exchange consists of three main stages: ventilation, diffusion and perfusion.

1. Ventilation: inflow and outflow of air into the lungs. This process is carried out through the respiratory mechanisms described above.

2. Diffusion: movement of gases between the alveoli and the blood along the concentration gradient. This process obeys Fick's law of diffusion:

V = (A × D × DP) / T

Here:

V is the diffusion rate

A is the diffusion surface

D is the diffusion coefficient

DP - partial pressure difference

T is the membrane thickness

The diffusion coefficient for oxygen is 20 times smaller than that of carbon dioxide, but due to the higher partial pressure difference of oxygen, it diffuses faster.

3. Perfusion: the flow of blood through the pulmonary capillaries. Venous blood from the pulmonary artery is saturated with oxygen and returns to the left heart through the pulmonary veins.

The efficiency of gas exchange depends on the following factors:

- Alveolar-capillary membrane surface and thickness

- Ventilation-perfusion ratio

- Hemoglobin content and its affinity for oxygen

- Blood flow rate

- Alveolar air composition

4.6. Breath control

Breathing is controlled by the central nervous system. The main respiratory center consists of a group of rhythmogenic neurons in the medulla oblongata.

The main structures involved in the control of breathing:

1. Dorsal and ventral respiratory centers in the medulla oblongata

2. Pneumotaxic center in Pons (Bridge of Varoli).

3. Cerebral cortex

4. Peripheral and central chemoreceptors

5. Mechanoreceptors (in the lungs and chest)

Breathing is controlled by the following mechanisms:

1. Chemical control: based on blood CO_2, O_2 and pH

- Increased CO_2 levels increase respiration

- A decrease in O_2 levels increases respiration (but this is weaker than the effect of CO_2)

- pH decrease increases respiration

2. Mechanical control: based on lung and chest mechanoreceptor signals

- Stretch receptors (Goering-Breyer reflex)

- Irritant receptors

- J-receptors

3. Central control: influence of cerebral cortex and limbic system

- Voluntary breathing

- Influence of emotional states

4. Other factors:

- Temperature (hyperthermia accelerates breathing)

- Hormones (for example, progesterone increases respiration)

- Medicines (eg opiates depress breathing)

4.7. The main pathologies of the respiratory system

Various diseases of the respiratory system affect lung function. The following are the most common pathologies and their effect on lung function:

1. Obstructive diseases:

- Bronchial asthma: temporary narrowing of the airways

- Chronic obstructive pulmonary disease (COPD): persistent narrowing of the airways

Effects: decrease in FEV1 (forced expiratory volume in 1 second), increase in RV

2. Restrictive diseases:

- Pulmonary fibrosis: severe stretching of lung tissue

- Pneumonia: lung inflammation

Effect: Decreased TLC and VC

3. Ventilation-perfusion disorders:

- Pulmonary embolism: blockage of pulmonary arteries

- Atelectasis: the collapse of a part of the lung

Effects: hypoxemia, hypercapnia

4. Diffusion disorders:

- Pulmonary edema: thickening of the alveolar-capillary membrane

- Emphysema: erosion of the alveolar wall

Effect: decrease in diffusion capacity

5. Violations of control:

- Central apnea: dysfunction of the respiratory center

- Obstructive sleep apnea: closure of the upper airway

Effects: hypoxemia, hypercapnia, decreased sleep quality

In the diagnosis and treatment of these pathologies, methods such as lung function tests, blood gas analysis, radiography, computer tomography are used.

5. Summary

Human respiratory system and lung physiology includes complex and multifaceted processes. Studying aspects such as the anatomical structure of the lungs, respiratory mechanisms, lung volumes, ventilation-perfusion ratio, gas exchange processes, and respiratory control helps to gain a deeper understanding of the respiratory system.

According to this study:

1. The lungs have a complex structure, and its anatomical features are designed to make gas exchange as efficient as possible.

2. The breathing process is carried out by complex mechanisms and is controlled by the central nervous system.

3. Lung volumes and capacities are important indicators in the assessment of lung function.

4. The ventilation-perfusion ratio differs in different parts of the lungs, and this affects the efficiency of gas exchange.

5. The process of gas exchange includes the steps of ventilation, diffusion, and perfusion, each of which is important.

6. Respiratory control is carried out by chemical, mechanical and central mechanisms.

7. Different pathological conditions affect different aspects of lung function, and their study is important for diagnosis and treatment of diseases.

This knowledge is important in the diagnosis and treatment of diseases of the respiratory system, as well as in the study of the physiology of breathing in special conditions such as working at high altitudes and swimming under water, improving artificial respiration devices.

The following directions for future research are suggested:

1. To study the effect of lung microbiome on respiratory physiology

2. Deeper study of the molecular mechanisms of respiratory control

3. To study the long-term effects of new diseases such as COVID-19 on lung function

4. Development of methods of treatment of respiratory diseases based on personalized medicine

5. Improving methods for early diagnosis of lung diseases using artificial intelligence and machine learning methods

This study serves to deepen knowledge in the field of respiratory physiology and lay the foundation for future research. This knowledge can be applied not only in the field of medicine, but also in fields such as sports physiology, environmental health and space medicine.

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