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HARDWARE-SOFTWARE COMPLEX FOR STUDYING THE EFFECT OF AIR COMPOSITION ON THE AERODYNAMIC PARAMETERS OF NASAL BREATHING

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Abstract. A description is given of the development of a hardware-software complex for studying the effect of air composition on the aerodynamic parameters of the nasal cavity in different breathing modes. The complex for determining the aerodynamic characteristics of nasal breathing includes a rhinomanometer with an olfactometric nozzle, and for determining the composition of air a measuring unit containing transducers reacting to the presence in the air of particles of different dispersion, formaldehyde, volatile organic compounds, carbon dioxide at specific indicators of temperature and humidity. Measured indicators of nasal breathing were air flow and pressure drop on the nasal cavity, the coefficient of aerodynamic nasal resistance, pneumatic power, and the olfactory sensitivity indices. The perspective of the work is to study the influence of the characteristics of inhaled air on the nasal resistance in different breathing patterns.

Keywords: air composition, nasal cavity.

Introduction. The work of the entire respiratory system depends on the anatomical features and functioning of the nasal cavity [1, 2]. Natural narrowing of the airways leads to the emergence of physiological aerodynamic resistance to airflow during breathing [3, 4]. The nasal cavity performs many physiological functions, the main of which are respiratory, olfactory, moisturizing, protective [4, 5]. If the first of these functions is paid a lot of attention at the evidence level, then the protective function of the nasal cavity is studied to the least extent. For example, the sizes of particles deposited in different parts of the respiratory tract are known, the influence of the structures of the nasal cavity on the nature of the air flow has been studied [6, 7]. However, the reaction of the mucous membrane of the nasal cavity to the composition of inhaled air — the content of dust particles and harmful substances typical for living conditions — has not been studied enough.

Therefore, the aim of the work is to develop a hardware-software complex to study the effect of air composition on the aerodynamic parameters of the nasal cavity in different breathing modes.

The results of the study. Airflow during nasal breathing experiences aerodynamic resistance from the intranasal structures. Moreover, more than half of it falls on the proportion of the nasal valve of the narrowest part of the nasal cavity [8, 9]. The rest of the resistance falls on air friction losses along the length of the nasal cavity, which is especially visible on the tomographic picture in the axial (see Fig. 1) and frontal (see Fig. 1, b) planes during contractions caused, for example, by rhinosinusitis and polypous processes (see Fig. 1, a, b - on the right), and on local resistances caused by the curvatures of the nasal septum (see Fig. 1, a, b - on the left). Regulation of the resistance of the nasal cavity creates conditions for various modes of breathing (calm, moderate and forced) and contributes to the efficiency of gas exchange in the alveoli of the lungs. The reduction in the internal air volume of the nasal cavity and, accordingly, the increase in resistance to air flow cause a change in the trajectory and speed of air through the initial sections of the respiratory tract [10, 11]. These changes in the endonasal volume can be caused by an external (exogenous) factor that affects the state of the cavernous venous tissue of the mucous membrane of the intranasal structures (mainly the concha). The speed of the air flow depends on the diameter of the nasal passages and, accordingly, on the volume of the intranasal structures. When the nasal passages are too narrow, or, conversely, or when breathing through the mouth, the volume flow of air through the nose significantly decreases and the exposure time of particles of aerosols and harmful substances increases, and the pressure on the mucosal receptor apparatus decreases, which reduces the reflexogenic and functional activity of the intranasal structures [12]. Therefore, it is advisable to study such changes in the filling of cavernous tissue with blood that occur reflexively under the influence of external stimuli, such as the dust content of inhaled air and the presence of harmful substances in the air.

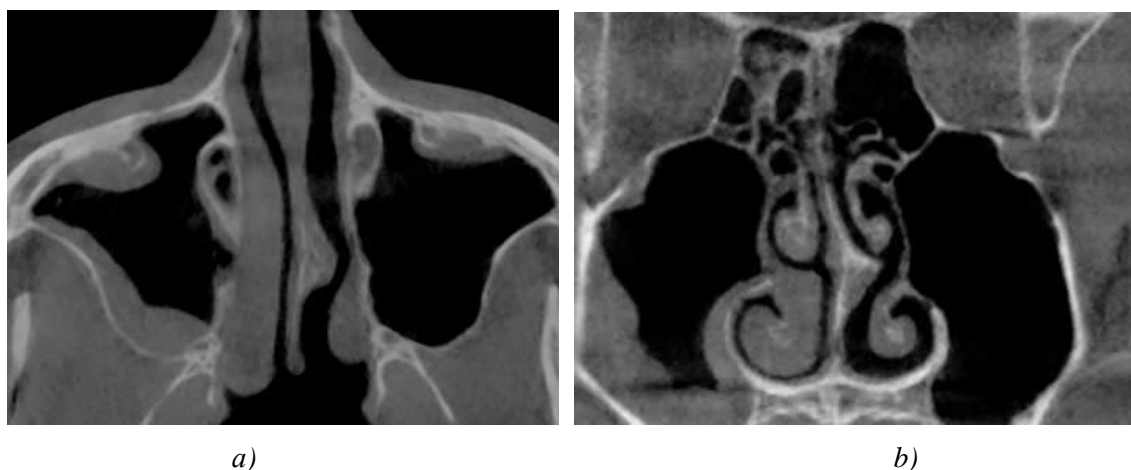


Fig. 1. Computed tomography of a patient with curvature of the nasal septum to the left and chronic rhinosinusitis: a) axial tomographic section; b) multiplanar reconstruction in frontal projection

For this purpose, a hardware-software complex (see Figure 2) has been developed to study the effect of air composition on the aerodynamic parameters of the nasal cavity in different breathing patterns. The complex for determining the aerodynamic characteristics of nasal breathing includes a rhinomanometer with an olfactometric nozzle [13, 14], and for determining the composition of the air - a measuring unit containing converters that react to the presence of particles of different dispersion, formaldehyde, volatile organic compounds, carbon dioxide in the air specific temperature and humidity indicators.

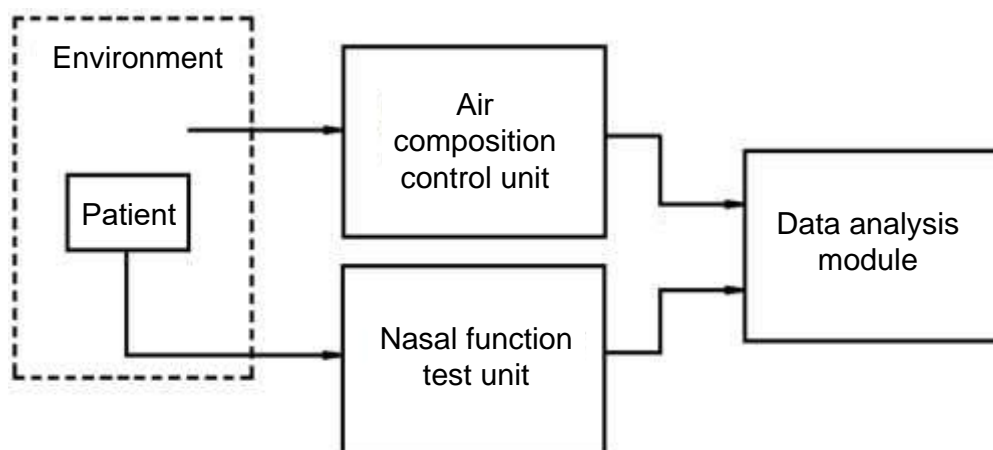


Fig. 2. Block diagram of the hardware-software complex for studying the effect of air composition on the aerodynamic parameters of the nasal cavity

In the control unit of air composition parameters, concentrations of suspended particles with PM_{2.5} PM₁₀ dispersity are investigated, which allows controlling the dust content of air, the concentration of formaldehyde HCHO, which can be contained in modern structural materials made on the basis of wood, volatile organic compounds that have high vapor pressure at normal room temperature [15]. Their high vapor pressure is the result of a low boiling point, which causes a large number of molecules to evaporate or sublime from the liquid or solid form of the compound and flow into the surrounding air — a feature known as volatility. Converters allow you to measure concentration.

Toluene (Methylbenzene) — C₇H₈

Hydrogen sulfide — H₂S

Ethanol — C₂H₅OH

Ammonia — NH₃

Hydrogen — H

Carbon dioxide concentration is also measured, as well as temperature and humidity parameters.

Measured indicators of nasal breathing were air flow and pressure drop on the nasal cavity, the coefficient of aerodynamic nasal resistance, pneumatic power, and the olfactory sensitivity indices.

The results of the nasal breathing test with measured respiratory air readings are transmitted via USB to the data analysis module for further processing and evaluation. Appearance of measuring blocks of hardware-software complex is shown in fig. 3. The unit for monitoring air parameters is implemented on the basis of the AIRMASTER air quality monitor. The unit for studying the function of nasal breathing is implemented on the basis of a computer rhinomanometer — a device for testing nasal breathing on the basis of a module for measuring flow-rate characteristics and an olfactometric nozzle produced by KNURE [16].



Fig. 3. Appearance of measuring blocks of hardware-software complex

Conclusions. The developed hardware and software complex allows you to investigate the effect of air composition on the aerodynamic parameters of the nasal cavity in different breathing modes. The presence in the air of particles of different dispersity, formaldehyde, volatile organic compounds, carbon dioxide for specific displays temperature and humidity. Measured indicators of nasal breathing were air flow and pressure drop on the nasal cavity, the coefficient of aerodynamic nasal resistance, pneumatic power, and the olfactory sensitivity indices. The speed of the air flow depends on the diameter of the nasal passages and, accordingly, on the volume of the intranasal structures. When the nasal passages are too narrow, or, conversely, or when breathing through the mouth, the volume flow of air through the nose significantly decreases and the exposure time of particles of aerosols and harmful substances increases, and the pressure on the mucosal receptor apparatus decreases, which reduces the reflexogenic and functional activity of the intranasal. The structure of the work is to study the influence of the characteristics of inhaled air on the nasal resistance in different breathing patterns.

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