Electrical conductivity of lungs and respiratory volumes in functional and diagnostic testing. Preliminary results.

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Abstract- **Physical and chemical properties of lungs are defined by the ratio of the pulmonary tissue volume, consisting of epithelial cells and alveolocyte, collagen and connective fibres, connective-tissue septum, blood and the volume of air contained in lungs. The diseases, which alter either ventilation or the blood-flow in lungs, should cause changes in their physical and chemical properties. The purpose of the current work was to determine the possibility of utilizing the electroimpedance tomography in the functional-diagnostic testing. Eight healthy volunteers, 10 patients with the diagnosis of lung cancer have been subjected to examination. Lungs electrical conductivity and pulmonary volumes were tested in the real time mode, utilized the 16-electrode single-frequency EIT system, developed in the Research Institute of Radio Engineering and Electronics of the Russian Academy of Sciences. The following data were evaluated: electrical conductivity index of lungs within the respiratory cycle, indexes of electrical conductivity, corresponding to standard pulmonary volumes (lungs vital capacity, respiratory volume, inspiratory capacity, expiratory reserve volume), lungs electrical conductivity gradient in health and during pathology. Changes of the lungs electrical conductivity at inhalation as well as at exhalation, dependence of electrical conductivity on respiratory rate were shown. The indexes of electrical conductivity, which correspond to standard lung volumes in health as well as at pathology, were calculated. The article is illustrated with electroimpedance tomograms and tables.**

Keywords- **impedance, lungs, testing.**

I. INTRODUCTION

Assessment of respiratory volumes is a quantitative estimation of various pulmonary disorders in functional and diagnostic testing. There are several methods for evaluation of respiratory volumes: the method of helium dilution, body plethysmography and others (1). The respiratory volumes, measured during different respiratory patterns, indicate changes of air quantity in airways and the respiratory zone of lungs. At the same time, air is one of the factors that affect not only the physical and chemical properties of the lungs, but their electrical conductivity. On the basis of the experiments correlation dependence was established between the air content in the pulmonary tissue and the total electrical resistance (impedance) (2). Changes in respiratory volumes in the health as well as at various diseases are accompanied by corresponding changes of electrical conductivity in airways and the lungs respiratory zone.

The aim of the research was to establish a possibility for utilization of electroimpedance tomography of lungs during functional and diagnostic testing.

II. MATERIALS AND METHODS

Eight subjects, comprising the reference group, as well as ten patients with lung cancer from the main group, were subjected to examination. Lung cancer was histologically confirmed in all the patients from the main group. The impedance lung tomography was performed with the help of the 16-electode single-frequency electroimpedance tomograph (2-8 kHz, 0,5 mA), developed at the Institute of Radio-Engineering of the Russian Academy of Science. To create the lung electroimpedance tomogram 16 round contact electrodes (∅20 mm), manufactured from aluminum, were fixed with an elastic band. To improve the skin contact electro conductive gel was applied to the inner side of the electrodes before their placement. Computer scanning of the chest organs was performed in the 5th intercostals zone. When the section was performed on the level V of the intercostals zone, the larger part of the chest were taken by part of the upper, middle and part of the lower lobes of the right lung as well as by the part of the upper and the lower lobes of the left lung. During the examinations the subjects were in a standing position; the following patterns of respiration were used: maximal inspiration, maximum expiration, free breathing.

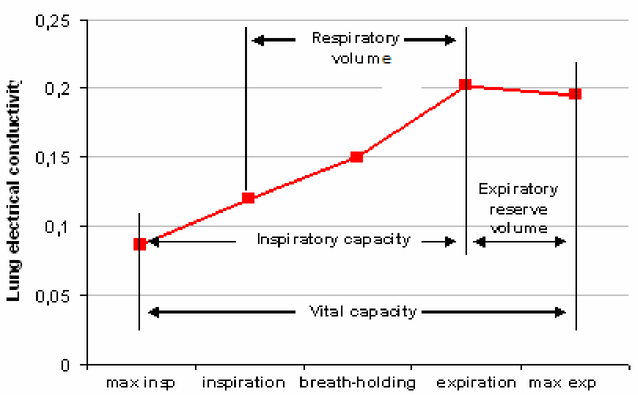

Fig. 1 Electrical conductivity of lungs and lungs volumes.

Table 1. Electrical conductivity index of lungs during the breathing cycle (quiet breathing).

		Right lung (M±σ)	Left lung (M±σ)
Airways	Inspiration	0,190±0,104	0,095±0,156
	Expiration	0,276±0,117	0,170±0,159
Respiratory zone	Inspiration	0,405±0,117	0,418±0,136
	Expiration	0,493±0,143	0,484±0,148

The electrical conductivity indices, which correspond to standard lung volumes, were evaluated: vital capacity (VC)– maximum air volume, expired after a maximum deep inspiration; respiratory volume (RV) – the volume of expired or inspired air at every breathing cycle; inspiratory capacity (IC)– the volume of maximum inspired air after a quiet expiration; expiratory reserve volume (ERV)- the volume of maximum expired air after a quiet expiration (fig. 1).

As bronchi diameter and the amount of air in them decreases, accompanied by a simultaneous increase of acini, which contain a large quantity of capillaries, the electrical conductivity of lungs changes. That is why we evaluated electroconductivity gradient at inspiration, expiration and quiet breathing, in other words, changes of electroconductivity in the direction from airways to the periphery of the respiratory zone with an increment of 0,10 of the scale rule. We examined 16 electrical tomograms of the chest organs that belong to healthy subjects and 20 electrical tomograms of the chest organs that belong to patients, suffering from lung cancer. The qualitative estimation comprised evaluation of lungs electrical conductivity during various respiration patterns and the electroconductivity gradient.

III. Results

A. Lungs electrical conductivity during a breathing cycle.

Synchronous changes of electrical conductivity of a patient's healthy left and right lung were recorded during the breathing cycle. Lung electrical conductivity, of adducting airways as well as of the respiratory zone, changes depending of the breathing cycle phase: at inhalation electrical conductivity decreases, at exhalation electrical conductivity increases (table 1).

A change of electrical conductivity of the left and the right lugs was recorded during the breathing cycle (table 1).All research revealed that the index of electrical conductivity of the left lung was below the index of electrical conductivity of the right one in all subjects from the reference group ($p>0,05$). It might probably be explained by anatomic particularities of the vascular system: the right pulmonary artery is somewhat wider then the left one, which influences blood filling of the right lung, and, consequently, its electrical conductivity. A correlation dependence was revealed between the breathing rate and the index of electrical conductivity: increase of respiratory rate was accompanied by increase of the lungs electrical conductivity, with the correlation coefficient between them being 0,6.

B. Electrical conductivity of lungs and respiratory volumes of the patients from the reference group.

Table 2 contains data of the electrical conductivity of lungs, corresponding to respiratory volumes of the patients from the reference group. All indices of electrical conductivity of the left lung, compared with the right one, in the airways and the respiratory zone, went down ($p>0,05$). When the change of electrical conductivity was examined, i.e. electroconductivity gradient, in the part from the airways to the respiratory zone, it was revealed that the index of electrical conductivity increased with increase of the increment number (table 3). But the electrical conductivity index that corresponded to the respiratory volume didn't change significantly.

Table 2. Lungs electrical conductivity (airways and respiratory zone) and lung volumes in patients from the reference group.

	Airways (M±σ)		Respiratory zone (M±σ)	
	Right lung	Left lung	Right lung	Left lung
Lungs vital capacity	0.108±0.08	0,125±0,06	0,130±0,09	0,132±0,08
Inspiratory capacity	0,115±0,06	0,127±0,05	0,107±0,03	0,123±0,09
Respiratory volume.	0,075±0,04	0,086±0,03	0,066±0,037	0,088±0,06
expiratory reserve volume	-0,007±0,04	-0,002±0,03	0,0023±0,08	0,008±0,06

Table 3. Electrical conductivity gradient in the subjects from the reference group (quiet breathing)

		Gradient of electrical conductivity (M±σ)				
		Increment 1	Increment 2	Increment 3	Increment 4	Increment 5
Right lung	Inhalation	0,190±0,10	0,220±0,11	0,290±0,12	0,353±0,13**	0,381±0,10***
	Exhalation	0,276±0,11	0,308±0,12	0,373±0,13	0,435±0,12**	0,476±0,12***
Left lung	Inhalation	0,095±0,15	0,129±0,17	0,196±0,19	0,243±0,12*	0,356±0,12***
	Exhalation	0,170±0,15	0,201±0,16	0,284±0,18	0,333±0,13	0,436±0,13***
Difference between inhalation and exhalation of the left lung (Respiratory volume)		0,086±0,02	0,088±0,03	0,079±0,03	0,081±0,06	0,094±0,03
Difference between inhalation and exhalation of the right lung (Respiratory volume)		0,075±0,04	0,072±0,05	0,088±0,05	0,090±0,05	0,080±0,05

*p<0,05; **p<0,01; ***p<0,001 (compared with the first column).

Table 4. Lungs electrical conductivity (airways and respiratory zone) and lung volumes in patients from the main group.

	Airways (M±σ)		Respiratory zone (M±σ)	
	Right lung	Left lung	Right lung	Left lung
Lungs vital capacity	0,105±0,09	0,030±0,04*	0,041±0,05	0,033±0,05
Inspiratory capacity	0,111±0,05	0,069±0,07	0,06±0,05	0,070±0,06
Respiratory volume.	0,059±0,06	0,034±0,04	0,025±0,06	0,033±0,05
expiratory reserve volume	0,006±0,07	0,039±0,04	-0,021±0,04	-0,037±0,05

*p<0,05; **p<0,01; ***p<0,001 (compared with the first column).

Table 5. Electrical conductivity gradient in the patients from the main group (quiet breathing)

		Gradient of electrical conductivity (M±σ)				
		Increment 1	Increment 2	Increment 3	Increment 4	Increment 5
Healthy lung	Inhalation	0,064±0,12	0,118±0,13	0,227±0,14**	0,341±0,15***	0,472±0,17***
	Exhalation	0,123±0,12	0,175±0,09	0,269±0,10**	0,387±0,11***	0,517±0,13***
Affected lung	Inhalation	0454±0,13	0,504±0,13	0,573±0,15	0,621±0,17*	0,545±0,08
	Exhalation	0,488±0,13	0,520±0,12	0,588±0,13	0,658±0,14**	0,610±0,11*
Difference between inhalation and exhalation of the healthy lung (Respiratory volume)		0,059±0,07	0,57±0,08	0,042±0,07	0,046±0,05	0,045±0,04
Difference between inhalation and exhalation of the affected lung (Respiratory volume)		0,034±0,04	0,016±0,03	0,015±0,04	0,037±0,05	0,065±0,05

*p<0,05; **p<0,01; ***p<0,001 (compared with the first column).

Table 6. Lungs electrical conductivity (airways) and lung volumes in patients from the reference and main groups.

	Health (M±σ)		Along cancer (M±σ)	
	Right lung	Left lung	Healthy lung	Affected lung
Lungs vital capacity	0.108±0.08**	0,125±0,0***	0,105±0,09	0,030±0,04
Inspiratory capacity	0,115±0,06	0,127±0,05*	0,111±0,05	0,069±0,07
Respiratory volume.	0,075±0,04*	0,086±0,03**	0,059±0,06	0,034±0,04
expiratory reserve volume	-0,007±0,04	-0,002±0,03*	-0,006±0,07	-0,039±0,04

*p<0,05; **p<0,01; ***p<0,001 (compared with the first column).

C. Electrical conductivity of lungs and respiratory volumes of the patients from the main group.

Table 4 contains data o f the electrical conductivity of lungs, corresponding to respiratory volumes of the patients from the main group.

A significant difference in electrical conductivity index was revealed, which corresponded to the lung vital capacity in the airways. The rest of the indices were considerably below in the affected part, although not significantly. When the gradient of electrical conductivity was examined, in the part from the airways to the respiratory zone, it was revealed that the index of electrical conductivity in the healthy lung increased with increase of the increment number; the affected lung didn't display any electrical conductivity increase (table 5). The electrical conductivity index that corresponded to the respiratory volume didn't change significantly.

IV. CONCLUSIONS

The data of the intragroup analysis are represented in the table 6. The indices of electrical conductivity that correspond to respiratory volumes are significantly lower inthe patient comprising the main group. It signifies that the subjects from this group have considerable lungs function disturbances. The above data prove that of electrical impedance tomography is a promising method in functional and diagnostic testing. In contrast to other methods diagnostics the current method makes it possible to examine the left and the right lung independently. Besides, in addition to quantitative information, one is capable of performing a visual estimation of the image. This is rather an important feature since it is not always easy to find the reason for the lung volumes decrease: different lung diseases can have similar indices of respiratory volumes. A visual estimation will considerably facilitate diagnostics.

V. REFERENCES

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