UDC 616.248-073.43

N. M. Leontieva*[1,2], I. V. Demko[1,2], E. A. Sobko[1,2], O. P. Ishchenko[1,2], I. A. Solovyova[1,2]

[1] — Federal State Budgetary Educational Institution of Higher Education "Krasnoyarsk State Medical University n.a. Prof. V. F. Voino-Yasenetsky" of the Ministry of Healthcare of the Russian Federation, Krasnoyarsk, Russia

[2] — Regional State Budgetary Healthcare Institution "Regional Clinical Hospital", Krasnoyarsk, Russia

IMPULSE OSCILLOMETRY FOR DIAGNOSIS OF EARLY CHANGES IN THE RESPIRATORY SYSTEM FUNCTIONAL STATE IN PATIENTS WITH MILD ASTHMA

Abstract

Currently, the analysis of respiratory function at suspicion of obstructive pulmonary diseases is recommended to start with spirometry as the most sensitive method of obstruction detection. However, data on informative value and specificity of a method are contradictory. To obtain reliable results good cooperation of the patient and health professionals is necessary. Impulse oscillometry is a noninvasive method of general respiratory resistance assessment, which does not require forced exhalations. The sensitivity and specificity of this method remain undecided as well as the obtained parameter interpretation. The **objective** of this work was to study opportunities of impulse oscillometry in diagnosis of early respiratory dysfunctions and identification of its most informative indicators correlating with parameters of spirometry and body plethysmography. **Materials and methods.** Patients with the established diagnosis of mild asthma (n=68) were examined. In 71 % of patients, obstructive respiratory dysfunction was revealed. In the control group (n=41) there were no abnormalities. **Results.** In most of patients with revealed via spirometry and body plethysmography obstructive disturbances the increase in indicators of absolute frequency dependence of the resistive component of the respiratory impedance at the oscillation frequency of 5 Hz and 20 Hz (Rrs5-Rrs20) and the reactance area (AX). Increase in Rrs5-Rrs20 was revealed in 48 (71 %) patients and the increase in AX was observed in 44 (65 %) of the surveyed patients, with 42 (61 %) patients without the increase of reactance (Xrs5) and resistance (Rrs5). **Conclusion.** The absolute frequency dependence of Rrs5-Rrs20 and AX are the most informative parameters of impulse oscillometry. In some patients the IOM findings were more significant in comparison with spirometry ones.

Key words: *asthma, airway obstruction, diagnosis, impulse oscillometry, body plethysmography, spirometry*

For citation: Leontieva N.M., Demko I.V., Sobko E.A. et al. IMPULSE OSCILLOMETRY FOR DIAGNOSIS OF EARLY CHANGES IN THE RESPIRATORY SYSTEM FUNCTIONAL STATE IN PATIENTS WITH MILD ASTHMA. The Russian Archives of Internal Medicine. 2019; 9(3): 213-221. [In Russian]. DOI: 10.20514/2226-6704-2019-9-3-213-221

DOI: 10.20514/2226-6704-2019-9-3-213-221

AX — reactance area, Co5 — coherence at oscillation frequency of 5 Hz, DXrs5 — expiratory flow restriction, fres — resonance frequency, Rrs — resistive component of the respiratory impedance, Raw — respiratory tract resistance, Xrs — reactive component of the respiratory impedance, BA — bronchial asthma, ITV — intrathoracic volume, VC — vital capacity, IOM — impulse oscillometry, TLC — total lung capacity, RV — residual volume, FEV_1 — forced expiratory volume in the first second of forced expiratory maneuver, MVR_{25-75} — mean volume rate of forced exhalation, FVC — forced vital capacity of lungs

* Contacts. E-mail: nigora-razzakova@rambler.ru

Introduction

Today, bronchial asthma (BA) is one of the most relevant health problems worldwide. According to official data, the annual increase in patients with the onset of the disease increased in the last decade [1]. Among the population of the Russian Federation, the incidence of BA for 2017 was 84.2 people per 100,000 people [2].

In the structure of morbidities, mild BA incidence occupies a leading position and occurs in 50–75 % of cases [3].

Based on forecasts, the number of patients with BA in the Russian Federation (both adults and children) will grow in the next decades, mainly due to early diagnosis of the disease [4, 5]. Thus, the study of clinical features of the mild course and early changes in the functional state of the respiratory system becomes particularly relevant.

Currently, the diagnosis of BA is established on the basis of the clinical picture and anamnestic data.

Functional diagnosis of the respiratory system allows to confirm the presence of the disease, to clarify the severity of bronchial obstruction, as well as its reversibility [6, 12, 26]. To date, the study of the respiratory system function in cases of suspected obstructive diseases is usually started with spirometry as the most sensitive method in the detection of bronchial obstruction [28–30]. However, the data on the informative value and specificity of the method are contradictory. The results of some studies indicate a weak relationship between the parameters of spirometry and BA manifestations [7–9, 23, 24]. It is important to remember that in situations when it comes to the examination of children and elderly patients, cooperation with whom is difficult, the diagnostic significance of spirometry is reduced. It should also be noted that classical spirometry makes it possible to assess the distal and proximal parts of the respiratory tract, which take part in forced exhalation. Functional changes in the early stages of bronchial obstruction have a latent nature due to the fact that they occur in peripheral bronchi that are not involved in the process of forced exhalation [23]. Thus, today there is an urgent problem of early diagnosis for the initial manifestations of peripheral bronchial obstruction. In recent years, oscillatory mechanics tests based on the technique of forced oscillations are increasingly used to identify early changes in the functional state of the respiratory system. The latest modification of the method — impulse oscillometry (IOM) — is more widely used. This technique allows to overcome the disadvantages of classical spirometry [25].

IOM is a non-invasive method of assessing total respiratory resistance in calm breathing, which does not require forced exhalations. The parameters calculated in IOM reflect the manifestations of obstruction, both in the central and peripheral bronchi. Data indicating patency disorders in small bronchi can be used both for early diagnosis of mild BA and for assessment of the efficacy of the therapy [10]. Baseline IOM parameters are the total amount of elastic and inertial resistance (the reactive component of respiratory impedance, or reactance (Xrs)) at a frequency of oscillations from 5 to 35 Hz and the resistive component of respiratory impedance (Rrs) [11].

To date, a number of studies aimed at assessing the capabilities of IOM have been conducted, but the interpretation of the indicators obtained during the examination, as well as the sensitivity and specificity of the method require further study [10, 17, 18, 20, 21].

The **objective** of this work was to study the capabilities of IOM in the diagnosis of early dysfunction of the respiratory system and to identify the most informative indicators of impulse oscillometry correlated with parameters of spirometry, body plethysmography.

Materials and methods

The main group of the study included patients diagnosed with mild BA (n=68), among them 27 (40 %) were male and 41 (60 %) were female. The median age was 26[22;33] years.

Verification of the diagnosis and the severity of BA was established in accordance with the recommendations set out in "Global strategy for the treatment and prevention of bronchial asthma", 2017 [12].

The control group included healthy subjects without clinical manifestations of lung disease and severe comorbidity (n=41), including 15 (37 %)

men and 26 (63 %) women. The median age was 25[21;32] years.

During the study, they used modern methods of functional diagnostics such as spirometry, body plethysmography and IOM. Examinations were conducted on the Master Screen Body (Jaeger, Germany) installation. Body plethysmography and spirometry were performed in the framework of the quality standards for studies of European Respiratory Society (ERS) and American Thoracic Society (ATS) [13,14]. IOM was carried out according to the recommendations of H. J. Smith, P. Reinhold et al. [15].

The study analyzed the following indicators of pulmonary functional tests:

1. Spirometric indicators — forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), Gensler index (FEV_1/FVC), Tiffeneau index (FEV_1/VC), volume rate in the middle section of the forced expiratory flow-volume curve between 25–75 % of the exhaled FVC (MVR_{25-75}).
2. Indicators of body plethysmography — total lung capacity (TLC), vital capacity (VC), residual volume (RV), the ratio of residual volume to total capacity (RV/TLC), intrathoracic gas volume (ITV), total, inspiration and expiration bronchial resistance parameters (Raw_t, Raw_{in}, Raw_{ex}).
3. Indicators of IOM — total respiratory resistance or respiratory impedance at the frequency of the oscillations of 5 Hz (Zrs5), the resistive component of respiratory impedance at the frequency of oscillations of 5 Hz and 20 Hz (Rrs5, Rrs20). Since the reactance at a frequency of 5 Hz (Xrs5) can assume negative values, its ratio to the predicted value was calculated by the difference between its predicted and obtained value (deltaXrs5) [16]. The frequency dependence was calculated as the absolute difference between the values of the resistive component of the respiratory impedance at the oscillation frequency of 5 Hz and 20 Hz (Rrs5-Rrs20), as well as a relative value. When determining the (relative) frequency dependence of Rrs, two methods of calculation recommended by different sources were used:
   D (Rrs%Rrs5) = (Rrs5 — Rrs20)/Rrs5*100 % [17]
   D (Rrs%Rrs20) = (Rrs5 — Rrs20)/Rrs20*100 % [18]
   The analysis includes DXrs5 parameters, which is defined as the difference between the mean values of Xrs5 on inhalation and exhalation, its increase is a functional sign of the expiratory flow restriction. The following IOM parameters were also evaluated during the work: resonance frequency (f_{res}), the area above the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX), which is sometimes called as Goldman triangle and coherence at the oscillation frequency of 5 Hz (Co5).

The results of spirometry and body plethysmography were analyzed taking into account the requirements of the ERS, ATS [13, 14] and the Federal clinical recommendations of the Russian respiratory society for spirometry method [19].

Mild severity of ventilation disorders was diagnosed with the decline in the Tiffeneau index <70 % of predicted, FEV_1 >70, moderate severity if FEV_1 index was in the range 60–69 %, and Tiffeneau index — <70 % of predicted, severe (significant) impairment was in case of FEV_1 values in the range of 50–59 % of predicted [13, 19].

The degree of severity of obstructive disorders according to the results of IOM was evaluated by changes in the main indicators of Rrs5 and deltaXrs5. For the resistive component of the respiratory impedance at the oscillation frequency of 5 Hz and 20 Hz (Rrs5, Rrs20) the values <150 % of predicted were considered as normal; for relative frequency dependence <35 %, for absolute frequency dependence (Rrs5-Rrs20) <0.08 kPa. DeltaXrs5 ≤0.15 kPa•s/l, the area above the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX) <0.33 kPa/l, DXrs5 <0.07 kPa•s/l, and the values of the resonance frequency of f_{res} in the range from 6 to 12 Hz were also taken into account within normal values [16, 20].

Taking into account what indicators exceeded normal values, conclusions were made about the level of respiratory tract (RT) damage. In case of their increase together with Rrs5 and Rrs20 increase and unchanged frequency dependence of Rrs5-Rrs20, obstruction associated with pathological process in the central RT was diagnosed. The increase of only Rrs5, leading to an increase in frequency dependence, was characterized by changes in peripheral RT. These changes, accompanied by an increase in deltaXrs5, indicated a significant and more severe degree of obstruction. Generalized obstruction was diagnosed in the detection of disturbances typical for obstructive disorders of peripheral and central RT.

The exceeding of the limits of the normal values of the area over the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX), which is sometimes referred to as the Goldman triangle, was also typical for the obstruction of the peripheral parts of the RT. The decrease in coherence at the frequency of oscillations of 5 Hz by less than 0.6 was considered as a sign of pathological heterogeneity of mechanical properties of the ventilation apparatus [21].

The results were processed using the Statistica-6.1 package for Windows. Quantitative values are presented as median (Me) and interquartile interval [Q_1;Q_3], where Q_1 is the 25 percentile, Q_3 is the 75 percentile. In the case of deviation from the normal distribution of samples determined by the Kolmogorov-Smirnov method and the Shapiro-Wilk test, the nonparametric Mann-Whitney U-test was used in the comparative analysis of groups on quantitative characteristics. Correlation analysis using Spearman rank correlation was used to assess the relationship between features. A very significant correlation was observed at r, corresponding to the level of statistical significance $p < 0.01$, a significant correlation — at r, corresponding to the level of statistical significance $p < 0.05$.

Results and discussion

According to spirometry data in the group of patients with mild BA, ventilation disorders of obstructive type were found only in 11 patients (16 %) (Table 1). In quantitative analysis of the FEV_1, mild airway patency disorders (APD) were reported in 3 (4 %) people, moderate APD — in 6 (9 %) patients, severe — in 2 (3 %) people, while the parameters of FVC and VC in all patients were within normal values. We found the decline of MVR_{25-75} in 13 patients (19 %). Similar results were demonstrated in a previous study by Pellegrino R. et al. (2005), which suggests that in the diagnosis of early bronchial obstruction, MVR_{25-75} may be more sensitive than FEV_1 [22].

According to body plethysmography the most pronounced changes were in bronchial resistance during exhalation (Raw_{ex}); this parameter increased in 32 (47 %) subjects, and increase in total bronchial resistance (Raw_t) was also reported in 15 (22 %) subjects and in bronchial resistance during inspiration (Raw_{in}) — in 9 (13 %) people.

In the control group bronchial resistance indices were within normal values in all subjects.

The results of IOM in the group of patients with mild asthma indicated an increase in the resistive component of respiratory impedance at the frequency of the oscillations of 5 Hz Rrs5 in 9 (13 %) patients, deltaXrs5 — in 10 (15 %) patients and an increase in Rrs20 — in 4 (6 %) of the patients. The comparison of the results for indicators in the group allowed to diagnose ventilation disorders of obstructive type, in 14 (21 %) patients, among them in 9 (13 %) patients moderate disorders were revealed and in 3 (4 %) — severe disorders and in 2 (3 %) — extreme disorders. Thus, in 5 (7 %) subjects changes based on IOM were more pronounced in comparison with spirometry.

In the analysis of IOM indicators in the group with mild BA, absolute frequency dependence Rrs5-Rrs20 was the most susceptible to changes, and its increase was found in 48 (71 %) people, of which 42 (61 %) patients had deltaXrs5 and Rrs5 within normal values. These changes were considered as an early sign of peripheral respiratory tract pathology. It is noteworthy that 44 (65 %) people had a larger area above the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX) and the resonance frequency f_{res} shifted to the high frequencies. Quantification of resistive component parameters of respiratory impedance at the frequency of oscillations equal to 5 and 20 Hz, the absolute frequency dependence Rrs5-Rrs20 and deltaXrs5 in patients with mild BA showed the presence of obstructive disorders on the level of the central respiratory tract in 3 patients (4 %), and 1 (2 %) patient was diagnosed with generalized obstruction. In the control group, the values of these indicators did not change.

As a result of the analysis of the relationship between findings of spirometry, body plethysmography and IOM in the group of patients with mild BA, direct and inverse highly significant ($p < 0.001$) correlations were identified.

Therefore, there was a strong positive correlation between bronchial resistance parameter Raw_{ex} and the area above the Xrs curve in the frequency

***Table 1.** Parameters of body plethysmography, spirometry and impulse oscillometry in the group of patients with mild asthma and the control group*

Parameters	Mild asthma, n=68		Control, n=41		Significance of differences
	Me[Q1;Q3]		Me[Q1;Q3]		
	n	1	n	2	
VC, %	68	100.9[91.15;109.55]	41	99.1[91.9;107.7]	$\rho_{1-2} = 0.72$
FVC, %	68	99.55[90.2;109]	41	102.8[95;110]	$\rho_{1-2} = 0.43$
FEV_1, %	68	90.75[82.5;98.45]	41	101.5[92.6;109]	$\rho_{1-2} = 0.001$
FEV_1/VC, %	68	77.55[72.25;80.6]	41	88[83;89.6]	$\rho_{1-2} <0.001$
FEV_1/FVC %	68	77.9[72.17;81.8]	41	86.44[82.08;88.37]	$\rho_{1-2} <0.001$
MVR_{75-25}, %	68	80.1[75.2;89.35]	41	89.4[82.2;96.8]	$\rho_{1-2} = 0.003$
TLC, %	68	104.6[99.25;110.75]	41	101[95;107.7]	$\rho_{1-2} = 0.057$
RV, %	68	112.05[97.45;137.2]	41	98.1[87.8;110.4]	$\rho_{1-2} = 0.003$
RV/TLC, %	68	106.55[92.05;126.35]	41	94.1[87.1;105.6]	$\rho_{1-2} = 0.013$
FRCρleth, %	68	106.9[88.7;117.2]	41	89.4[83;103.6]	$\rho_{1-2} = 0.001$
Raw_t, kPa•s/l	68	0.21[0.15;0.29]	41	0.16[0.12;0.2]	$\rho_{1-2} <0.001$
Raw_{ex}, kPa•s/l	68	0.23[0.18;0.35]	41	0.2[0.15;0.24]	$\rho_{1-2} = 0.002$
Raw_{in}, kPa•s/l	68	0.18[0.14;0.26]	41	0.19[0.14;0.22]	$\rho_{1-2} = 0.438$
Zrs5, %	68	127.2[108;138.7]	41	106.4[97.2;122.3]	$\rho_{1-2} <0.001$
Rrs5, %	68	128.7[95.2;145.2]	41	102[87.1;112]	$\rho_{1-2} <0.001$
Rrs20, %	68	92.2[73.05;117.55]	41	94.5[73.3;99]	$\rho_{1-2} = 0.247$
(Rrs5-Rrs20)/Rrs5, %	68	20.3[11.4;28.1]	41	12.2[8.6;15.9]	$\rho_{1-2} <0.001$
(Rrs5-Rrs20)/Rrs20, %	68	25.4[13.0;39.1]	41	13.9[9.4;19.0]	$\rho_{1-2} <0.001$
Rrs5-Rrs20, kPa•s/l	68	0.09[0.07;0.14]	41	0.04[0.03;0.06]	$\rho_{1-2} <0.001$
deltaXrs5, kPa•s/l	68	0.1[0.08;0.14]	41	0.09[0.07;0.12]	$\rho_{1-2} = 0.038$
AX, kPa/l	68	0.37[0.2;0.56]	41	0.18[0.15;0.21]	$\rho_{1-2} <0.001$
DXrs5, kPa•s/l	68	0.07[0.035;0.125]	41	0.04[0.02;0.05]	$\rho_{1-2} <0.001$
Co5	68	0.78[0.67;0.88]	41	0.72[0.67;0.79]	$\rho_{1-2} = 0.046$
fres, Hz	68	16.5[12.5;19]	41	9[7;11]	$\rho_{1-2} <0.001$

Note: The significance of differences between groups is calculated using the Mann-Whitney test; differences are significant at ρ <0.05; n is the number of observations

range from 5 Hz to f_{res}, (AX) (r = 0.73, ρ <0.001). Also mean, direct, correlation for Raw_{in}, Raw_t and AX (r = 0.67, ρ <0,001, r = 0.68, ρ <0.001, respectively), mean direct, highly significant correlation of these parameters with the resonant frequency f_{res} (r = 0.53, ρ <0.001, r = 0.54, ρ <0.001, respectively) were found (Fig. 1). Thus, in most patients with clinical manifestations of bronchial obstruction and increased bronchial resistance, there was an increase in the area above the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX).

We also found a mean direct correlation of the Rrs5 parameter with bronchial resistance indicators Raw_{ex} (r = 0.67, ρ <0.001), Raw_{in} (r = 0.66, ρ <0.001), Raw_t (r = 0.67, ρ <0.001) and between Rrs20 and Raw_{ex} (r = 0.54, ρ <0.001), Raw_{in} (r = 0.53, ρ <0.001), Raw_t (r = 0.52, ρ <0.001) (Fig. 2).

Correlation analysis of spirometry and IOM indicators revealed mean inverse correlation between MVR_{25-75} and the following indicators: Rrs5 (r = –0.56, ρ <0.001), AX (r = –0.59, ρ <0.001), absolute frequency dependence Rrs5-Rrs20 (r = –0.50, ρ <0.001) and resonance frequency f_{res} (r = –0.66, ρ <0.001). Moderate inverse correlation between the Rrs20 indicator and Tiffeneau index (r = –0.50, ρ <0.001), Gensler index (r = –0.54, ρ <0.001), and moderate inverse correlation between the absolute frequency dependence Rrs5-Rrs20 and FEV_1 ($r = -0.46$, $p < 0.001$), Tiffeneau index ($r = -0.49$, $p < 0.001$), Gensler index ($r = -0.45$, $p < 0.001$) (Fig. 3) were found.

The results obtained suggest that the IOM parameters, such as the area above the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX), the absolute frequency dependence Rrs5-Rrs20 and the resistive component of the respiratory impedance at the oscillation frequency of 5 along with the parameters of spirometry MVR_{25-75}, FEV_1, FEV_1/VC, FEV_1/FVC can indicate the presence of airway patency impairment.

In addition, in the group of patients with mild BA, moderate inverse correlation was established between the VC and FVC parameters and Rrs5 ($r = -0.34$, $p = 0.005$, $r = -0.35$, $p = 0.003$, respectively), the absolute frequency dependence Rrs5-Rrs20 ($r = -0.31$, $p = 0.011$, $r = -0.36$, $p = 0.002$, respectively), AX ($r = -0.32$, $p = 0.009$, $r = -0.34$, $p = 0.005$, respectively) and the resonance frequency f_{res} ($r = -0.38$, $p = 0.002$, $r = -0.43$, $p < 0.001$, respectively) (Fig. 4).

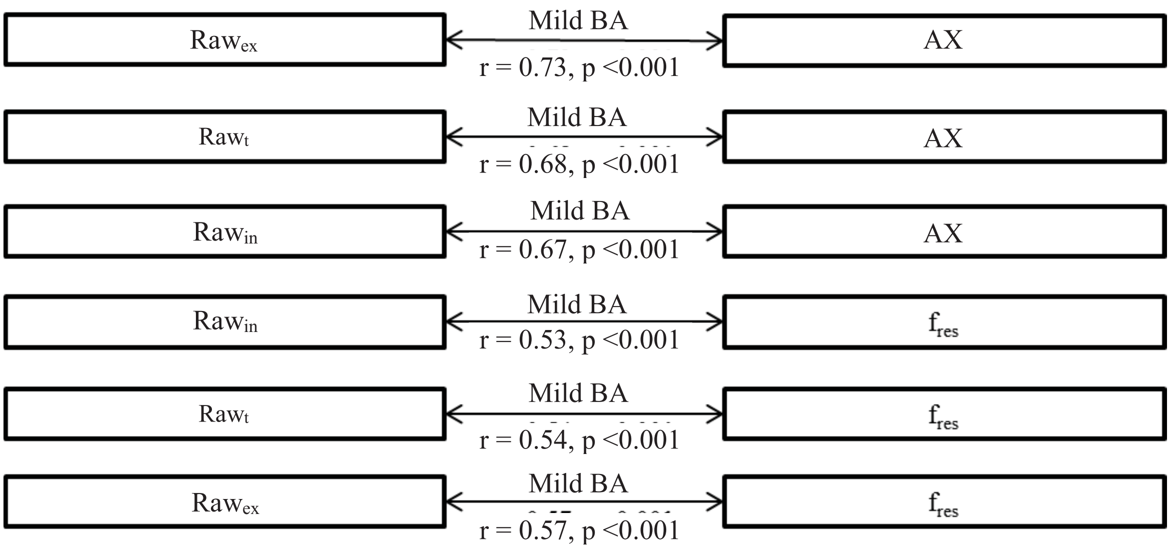

Figure 1. *Correlation of bronchial resistance and IOM parameters in the group of patients with mild asthma*

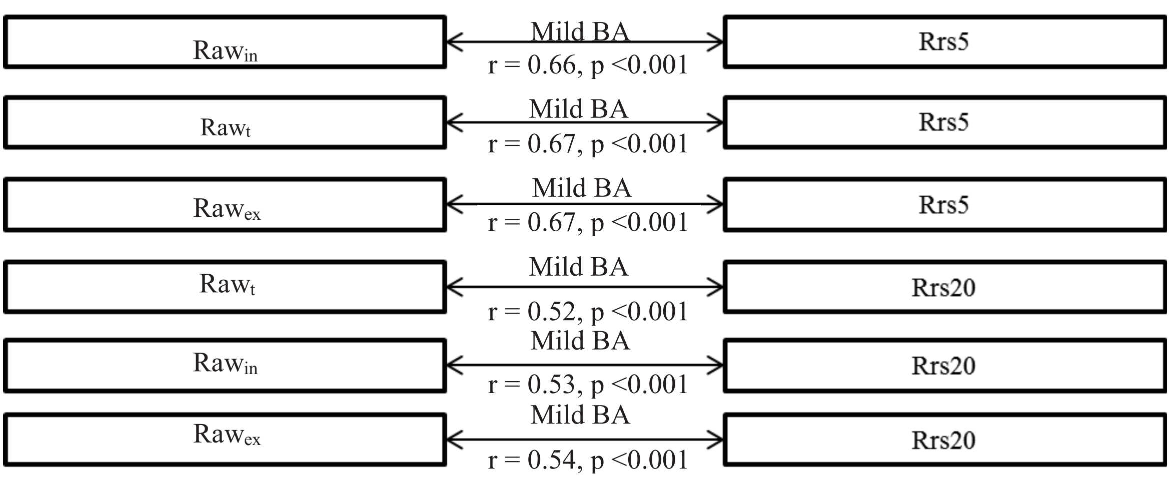

Figure 2. *Correlation of bronchial resistance and the resistive component of the respiratory impedance at the oscillation frequency of 5 and 20 Hz in the group of patients with mild asthma*

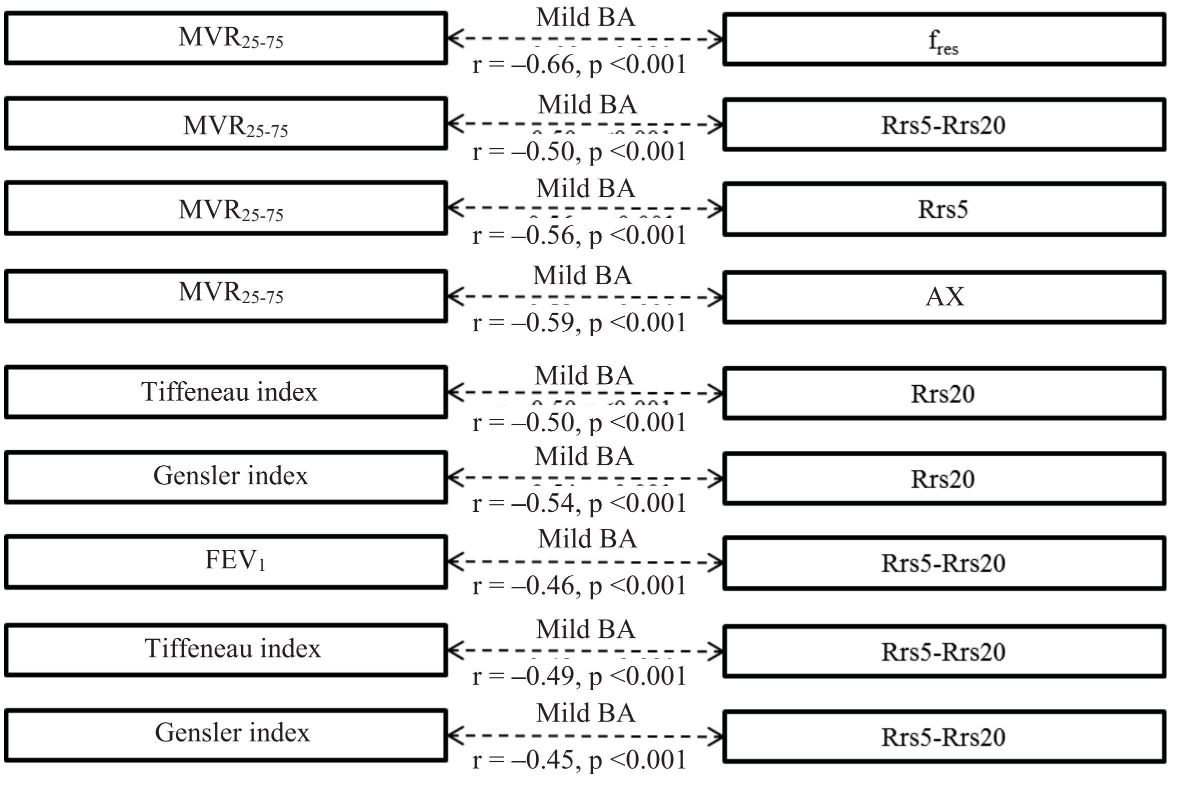

Figure 3. *Correlation of respiration mechanics parameters (MVR_{25-75}, Tiffeneau index, Gensler index, FEV_1) with IOM parameters, resistive component of the respiratory impedance at the oscillation frequency of 5 and 20 Hz, absolute frequency dependence, resonance frequency f_{res} and AX in the group of patients with mild asthma*

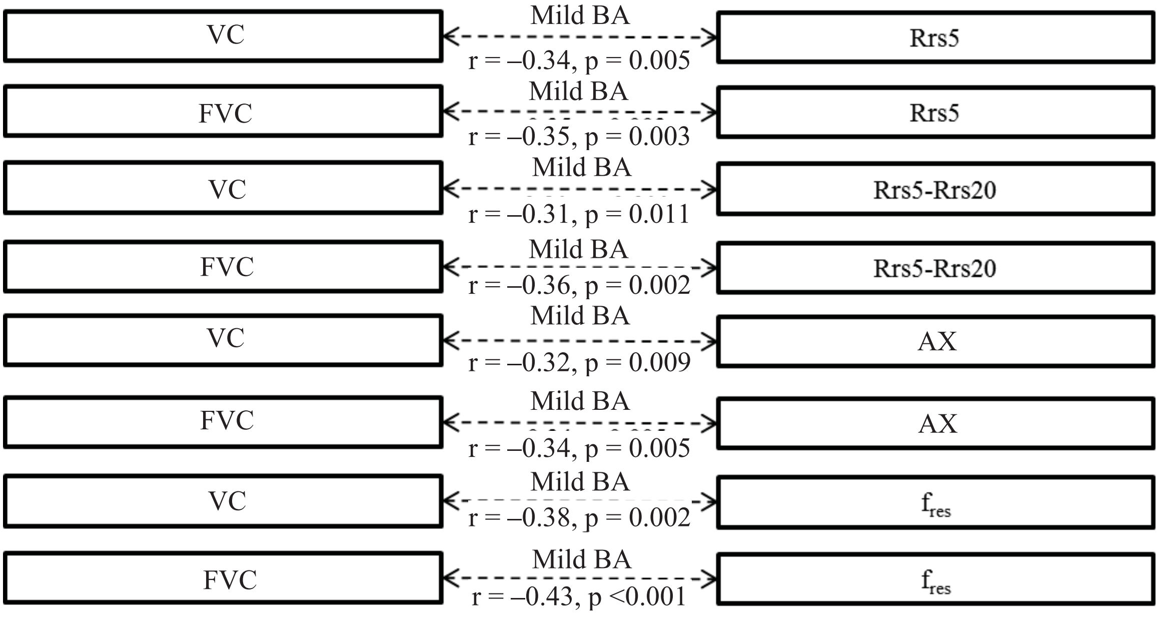

Figure 4. *Correlation of lung volumes (VC, FVC) and the resistive component of the respiratory impedance at the oscillation frequency of 5 and 20 Hz, absolute frequency dependence Rrs, resonance frequency f_{res} and AX in the group of patients with mild asthma*

Thus, the results of the analysis showed that in patients with ventilation disorders of obstructive type, bronchial resistance indicators are significantly correlated with all the main parameters of IOM. The most informative indicators of IOM were absolute frequency dependence Rrs5-Rrs20 and the area above the curve Xrs in the frequency range from 5 Hz to f_{res}, (AX); these indicators were closely correlated with the magnitude of bronchial resistance, and in inverse proportion to rate indicators, such as FEV_1, MVR_{25-75}, FEV_1/VC, FEV_1/FVC. Similar correlations were observed between the VC, FVC and resistive component of the respiratory impedance at the oscillation frequency of 5, 20 Hz Rrs5, Rrs20. Therefore, the lower the rate and the greater the capacity, the greater the absolute frequency dependence Rrs5-Rrs20, AX and Rrs5, Rrs20.

In the future, it is planned to conduct a study with the expansion of the groups of subjects and a more in-depth analysis of the relationship between the indicators of functional tests, including IOM with the severity of obstructive disorders in patients with bronchial asthma.

Conclusion

According to the results of the study, the following conclusions can be made:

1. IOM parameters are significantly correlated with body plethysmography and spirometry parameters, to a greater extent with indicators of bronchial resistance
2. The absolute frequency dependence Rrs5-Rrs20 and the area above the Xrs curve in the frequency range from 5 Hz to f_{res}, (AX) are the most informative parameters of the IOM and are in a closer correlation with the respiratory mechanics parameters
3. Indicators of the resistive component of the respiratory impedance at the oscillation frequency of 5 Hz, 20 Hz, Rrs5, Rrs20 and deltaXrs5 allow to differentiate the localization of the pathological process in the central and peripheral RT and, possibly, in some cases, can be more informative than basic parameters of spirometry; in 5 subjects (7 %), according to IOM, changes were more pronounced in comparison with spirometry.

Conflict of interests

The authors declare no conflict of interests.

References:

1. Nunes C., Pereira A.M., Morais-Almeida M. Asthma costs and social impact. Asthma Research and Practice. 2017; 3: 1. DOI: 10.1186/s40733-016-0029-3.
2. Morbidity of the whole population of Russia in 2017: Statistical materials. P. I. M.: The Russian Federation Ministry of Health, Department of Monitoring, Analysis and Strategic Health Development, Federal State Budgetary Institution «Central Research Institute for Health Organization and Informatization» of the Russia Health Ministry. 2018; 97-99 [In Russian].
3. Dusser D., Montani D., Chanez P., et al. Mild asthma: an expert review on epidemiology, clinical characteristics and treatment recommendations. Allergy. 2007; 6 (62): 591–604. DOI:10.1111/j.1398-9995.2007.01394.x.
4. Pribylova N.N., Pribylov S.A., Mahova O.Ju. Prevalence, features of the clinical course and treatment, phenotypes of bronchial asthma in the Kursk region according to the register. Modern Problems of Science and Education. 2016; 5: 120 [In Russian].
5. Arhipov V.V., Belousov D.Ju., Lazareva N.B., et al. Bronchial asthma — problem study. Good Clinical Practice. 2006; 3:31 [In Russian].
6. Mineev V.N. Sorokina L.N., Njoma M.A. Polymorphism of a protein gene STAT6 and bronchial asthma. Kazan medical journal. 2009; 9 (3): 102-103 [In Russian].
7. Namazova L.S., Ogorodova L.M., Geppe N.A., et al. Bronchial asthma. Pediatric Pharmacology. 2006; 3 (2):12-25 [In Russian].
8. Beilby J. Asthma monitoring in primary care: time to gather more robust evidence. Primary Care Respiratory Journal. 2012; 21:1-7. DOI: 10.4104/pcrj.2012.00005.
9. Boulay M.E., Boulet L.P. Discordance between asthma control clinical, physiological and inflammatory parameters in mild asthma. Respiratory Medicine. 2013; 107(4): 511–518. DOI:10.1016/j.rmed.2012.12.015.
10. Shi Y., Aledia A.S., Galant S.P., et al. Peripheral airway impairment measured by oscillometry predicts loss of asthma control in children. The Journal of Allergy and Clinical Immunology. 2013; 131(3): 718–723. DOI: 10.1016/j.jaci.2012.09.022.
11. Santos K. dos, Kviecinski M.R., Silva J. da. Diagnosis of asthma: the challenge goes on. The Journal of Asthma:

Official Journal of the Association for the Care of Asthma. 2016; 53(2): 113. DOI:10.3109/02770903.2015.1060610.
12. Global Strategy for Asthma Management and Prevention, Global Initiative for Asthma (GINA) 2017.
13. Wanger J., Clausen J.L., Coates A. et al. Standardisation of the measurement of lung volumes. European Respiratory Journal. 2005; 26 (3): 511-522. DOI: 10.1183/09031936.05.00035005.
14. Maclntyre N., Crapo R.O., Viegi G. et al. Standardisation of the single-breath determination of carbon monoxide uptake in the lung. European Respiratory Journal. 2005; 26 (4): 720-735. DOI: 10.1183/09031936.05.00034905.
15. Smith H.J., Reinhold P., Goldman M.D. Forced oscillation technique and impulse oscillometry. In: Gosselink R., Stam H., eds. Lung function testing. Sheffield, UK: European Respiratory Society. 2005; 72—105.
16. Savushkina O. I., Chernjak A.V. Pulmonary function tests: from theory to practice. M.: STROM. 2017; 192 p. [In Russian].
17. Nekljudova GV, Chernjak AV. Impulse oscillometry in the evaluation of the provocative test. Collection of abstracts of the 15th Respiratory diseases National Congress. Moscow, November 29 — December 2, 2005. Pulmonology. 2005, application: 213 (785) [In Russian].
18. Chernjak A.V., Amelina E.L. Use of impulse oscillometry for patients with a mucoviscidosis. Pulmonology. 2005; 2: 84-88 [In Russian].
19. Chuchalin A.G., Aĭsanov Z.R., Chikina S.Ju., et al. Federal clinical guidelines of the Russian respiratory society on the use of the spirometry method. Pulmonology. 2014; 6:11-24 [in Russian].
20. Winkler J., Hagert-Winkler A., Wirtz H., et al. [Die moderne impulsoszillometrie im Spektrum lungenfunktioneller Messmethoden]. Pneumologie. 2009; 63 (8): 461- 469. DOI: 10.1055/S-0029-1214938 [In German].
21. Chernjak A.V., Kameneva M.Ju., Krjukov E.V., et al. Possibilities of impulse oscillometry in the diagnosis of airway obstruction of mild severity. Pulmonology. 2018; 28 (4): 391-398 [In Russian].
22. Pellegrino R., Viegi G., Brusasco V. et al. Interpretative strategies for lung function tests. European Respiratory Journal. 2005; 26: 948–968.
23. Chuchalin A.G. Bronchial asthma and asthma-like states. Russian Medical Journal. 2002; 5: 232 [in Russian].
24. Cowie R. L., Underwood M. F., FieldCan S. K. Asthma symptoms do not predict spirometry. Canadian Respiratory Journal. 2007; 6 (4): 339-342 DOI: 10.1155/2007/816132.
25. Kirjuhina L.D., Kameneva M.Ju., Novikova L.N. Opportunities of impulse oscillometry in the diagnosis of a restrictive variant of ventilation disorders. Medical sciences. 2017; 59 (5): 136-141 [In Russian].
26. Sobko E.A., Ishchenko O.P., Demko I.V., et al. Evaluation of the clinical and functional status in patients with bronchial asthma. Siberian Medical Review. 2010; 3: 75-79 [In Russian].

Article received on 06.03.2019
Accepted for publication on 13.03.2019