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Impulse oscillometry in evaluation bronchial hyperresponsiveness in patients with persistent allergic rhinitis

Impulsna oscilometrija u proceni bronhijalne hipereaktivnosti kod bolesnika sa perzistentnim alergijskim rinitisom

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Abstract

Background/Aim. Impulse oscillometry (IOS) is a method for estimating lung function which is used for early detection of bronchial hyperresponsiveness (BHR) and asthma. The aim of the study was to determine the prevalence of BHR, the correlation between spirometry and IOS and sensitivity and specificity of IOS in proving BHR in patients with persistent allergic rhinitis. **Methods.** The study included 81 patients with allergic rhinitis. From all of them, medical history was taken, allergy testing was done, as well as measurements of parameters of lung function by the IOS and spirometry before and after nonspecific bronchial provocation test with histamin via Aerosol provocative system. Changes of the IOS parameters to fall in FEV1 of 20% were measured and compared with changes in the spirometry parameters. After bronchial challenge test subjects were divided into two groups: the group with BHR (group 1) and that without BHR (group 2). **Results.** The mean age of participants was 25.7 ± 5.7 years, and 50.5% were men. Out of the total number of subjects with allergy rhinitis, 56 (58.9%) had a positive BPT. After bronchoprovocation an average increase in the group 1 was 88.15% for Rrs5, 111.98% for Fres, and for AX 819.69%. The high degree of correlation between the IOS and spirometry was proven in the group 2, while the whole group 1 had a weak correlation between parameters of these two methods. High sensitivity and low specificity for Rrs5 and Fres compared to FEV1 in diagnosing BHR was proven. **Conclusion.** The study demonstrated a high prevalence of BHR in the study group of patients with persistent allergic rhinitis, poor correlation in relation to the spirometric measurements in the group with BHR and a high sensitivity and low specificity of IOS for the detection of early changes in the airways.

Key words:
rhinitis, allergic; oscilometry; spirometry; respiratory function test; diagnosis; sensitivity and specificity.

Apstrakt

Uvod/Cilj. Impulsna oscilometrija (IOS) je metod za procenu funkcije pluća koji se koristi za rano otkrivanje bronhijalne hiperreaktivnosti (BHR) i astme. Cilj rada je bio da se utvrde učestalost BHR, korelacija između IOS i spirometrije, senzitivnost i specifičnost IOS u dijagnozi BHR kod bolesnika sa perzistentnim alergijskim rinitisom. **Metode.** Od 81 ispitanika sa alergijskim rinitisom uzeta je anamneza, urađeno je alergološko testiranje, merenja funkcije pluća pomoću spirometrije i IOS pre i posle nespecifičnog bronhoprovokativnog testa (BPT) sa histaminom preko Aerosol provokacionog sistema. Merene su promene parametara IOS do pada FEV1 za 20% koje su upoređivane sa promenama spirometrijskih parametara. Nakon BPT ispitanici su bili podeljeni u grupu sa BHR (grupa 1) i bez BHR (grupa 2). **Rezultati.** Prosečno životno doba ispitanika iznosilo je 25,7 ± 5,7 godina, a 50,5% su bili muškaraci. Od ukupnog broja ispitanika sa alergijskim rinitisom 56 (58,9%) su imali pozitivan BPT. Posle bronhoprovokacije u grupi 1 prosečno povećanje za Rrs5 bilo je 88,15%, za Fres 111,98%, za AX 819,69%. Visok stepen korelacije dokazan je između IOS i spirometrije u grupi 2, dok je u grupi 1 utvrđena slaba korelacija između vrednosti parametara ova dva metoda. Dokazana je visoka senzitivnost i niska specifičnost za vrednosti Rrs5 i Fres u odnosu na FEV1 u dijagnostikovanju BHR. **Zaključak.** Dokazana je visoka prevalencija BHR u grupi pacijenata sa perzistentnim alergijskim rinitisom, loša korelacija u odnosu na spirometrijska merenja u grupi sa BHR i visoka osetljivost i niska specifičnost IOS u detekciji ranih promena u disajnim putevima.

Ključne reči:
rinitis, alergijski; oscilometrija; spirometrija; respiratorna funkcija, testovi; dijagnoza; osetljivost i specifičnost.

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Introduction

Allergic rhinitis (AR) is a global problem which occurs in 500 million people around the world. AR is a chronic inflammation of the mucous membranes of the nose that occurs after exposure to allergens that trigger inflammation of the nasal mucosa, which is mediated by immunoglobulin class E. AR symptoms are sneezing, obstruction in the nose, increased secretion from the nose, nasal itching and often hyposmia [1].

The guidelines Allergy Rhinitis and Its Impact on Asthma (ARIA) which define and propose standard diagnostic and therapeutic procedures are widely accepted in the world. According to the ARIA, AR is divided regarding the time of occurrence and duration of symptoms (intermittent and persistent) and regarding the severity (mild and moderate – severe), and is considered a major risk factor for asthma [1].

According to the latest guidelines of the Global Initiative of Asthma (GINA) from 2015 [2] asthma is defined as a heterogeneous disease (more phenotypes) which is usually characterized by chronic inflammation of the airways. The diagnosis of asthma is made on the basis of history data of respiratory symptoms, clinical findings, allergy tests and bronchodynamic tests for the detection of bronchial hyperresponsiveness (BHR) according to GINA guidelines. People suffering from asthma in 70–90% of cases are also suffering from AR [3]. Patients with AR have often expressed BHR without symptoms displayed, in other words, they have „asthma without asthma“ [4].

BHR was defined as a greater tendency to change the lumen of the airways in response to different substances or provocative stimuli. BHR is proving by bronchodynamic tests bronchodilator test (BDT) and bronchial challenge test (BCT) [2]. In patients with AR according to the recommendations of the ARIA there is an indication for bronchodynamic tests to prove any BHR [5].

AR and asthma are often associated disorders, covered by the term „one airway disease“. The concept of a single airway is based on the diagnostic and therapeutic implications [6, 7].

Impulse oscillometry [Impulse Oscillometry System (IOS)] is still non-standardized method of measuring lung function, which is used for determining the respiratory impedance over input sound pulses into the airway, and it is a result of interaction between the resistance (Rrs) and reactivity (Xrs) of the respiratory system [8]. Testing is conducted by impulse oscillometer and lasts only 20 to 30 sec and does not depend on the cooperation of the patient contrary standard methods for estimating pulmonary function, which is perfect in pulmonology and pediatric patients [9]. This method provides specific and additional information on standard measurements of lung function and is suitable for the detection of BHR [10].

The aim of the study was to determine the prevalence of BHR, a correlation between IOS and spirometry, and the sensitivity and specificity of respiratory impedance method compared to the conventional methods for estimating lung function in detection of BHR in patients with persistent AR.

Methods

Criteria used for selecting subjects for the study were as follows: patients of both sexes, non-smokers, aged 18–40 years, with the evidence of persistent type AR of and fulfilled ARIA criteria [1]. Criteria for excluding patients from the study were: contraindications to perform spirometry and bronhoprovocating test according to the recommendations of the American Thoracic Society (ATS) and the European Respiratory Society (ERS) [11, 12], a contraindication for implementing tests for allergies according to the ARIA guidelines [1] and non-cooperation.

After BCT, subjects were divided into the group with BHR (group 1) and the one without BHR (group 2). The expected size of the sample was approximately 80 patients (± 10%).

This study was approved by the Ethics Committee of the Military Medical Center in Novi Sad, Serbia. All participants received instruction for BCT preparation, which contained a list of medicines and foods that should not be taken before testing (no taking short-acting beta agonists for 6 hours, long acting beta agonists for 12 hours, anticholinergics for 12 hours before the test, to avoid coffee, carbonated juices, tea and chocolate). The subjects also received instructions not to take antihistamines and corticosteroids that could modify the clinical picture of persistent AR and influence results of the prick test. The test was carried out in the following order: first, in all patients the diagnosis of persistent AR was on or off according to the ARIA guidelines [1] on the basis of a patient's history and alergology skin test. On the basis of the history data on the duration of symptoms, it was determined whether the patients with AR had intermittent or persistent type of the disease and, according to the intensity of the symptoms, whether they had mild od moderate – severe form of the disease [1].

The diagnosis of AR according to the ARIA guidelines [1] was based on a history of symptoms of AR and results of epicutaneous prick test with standard inhalant allergens [13]. The prick test was done with standard set of 10 inhalation allergens with saline solution as negative control and with 0.5% solution of histamine as positive control. Allergic hypersensitivity to certain allergens was considered positive if the papules at the site of allergen application were 3 or more millimeters in diameter.

Basic measurements of spirometry and IOS parameters were performed in both groups. The IOS was performed as recommended by the constructor (Impulse oscilometer series Master Screen IOS Care Fusion, Jaeger, Wurtzburg, Germany) [8]. Following parameters of the IOS were measured: total impedance at 5 Hz – Zrs5 (kP/L/s), total resistance at 5 Hz – Rrs5 (kP/L/s), resistance at 20 Hz – Rrs20 (kP/L/s), differential resistance at 5 and 20 Hz – Rrs5-Rrs20 (kP/L/s), a reactance at 5 Hz – Xrs5 (kP/L/s), Δ Xrs5 (Xrs5pred – Xrs5act); resonant frequency (Fres) (L/s), asthma index or Goldman index – AX (L/s). The results measured by the IOS were compared with the norms of the constructor [8].

Spirometry was performed on a series spirometer (Master Screen IOS, Care Fusion, Jaeger, Wurtzburg, Germany) by the standards of the ATS and ERS [14, 15], and following parameters were determined: forced vital

capacity (FVC) [1], forced expiratory volume in one second (FEV1) [1], the ratio of FEV1/FVC (%); forced expiratory flow at 50% of expiratory flow – (FEF 50) [1]; the ratio of forced expiratory flow at 25% and 75% of expiratory flow – [FEF 25/75 (%)]. The results of spirometric measurements were compared with the norms of the European Coal and Steel Community (ECSC) [14, 15].

Nonspecific BPT with histamine was performed with spirometry and the IOS through the Aerosol Provocation System (APS) (Care Fusion, Jaeger, Wurtzburg, Germany). Aerosol provocation system has a compressor with a flow rate of 7 L/min and working pressure of 0.9 bar. The system supports powerful jet nebulizer that produces aerosol. The nebulizers used for APS is a "DeVilbiss 646", and has particle diameter of 4.5 μm, and strength of 1,400 mg/min. APS has software which has two central parts, the test sequence and the observation module. Nonspecific BPT with histamine was done under the guidelines of the ATS and the ERS. Provocation test was performed by the first executed basic measurements of pulmonary function following with measurements after inhalation of bronchoprovocative substances. The first step included inhalation of l mL of physiological saline (NaCl 0.9%) and then the test was continued using the same model of histamine inhalation solution in increasing concentrations of 0.03, 0.06, 0.12, 0.25, 0.5, 1.0, 2.0 mg/mL. Stock solution was prepared in concentrations of 32 mg/mL and 4 mg/mL, at the Institute of Pharmacy, Military Medical Academy, Belgrade, using a software which automatically assigns the set of increasing concentrations from 0.03 to 2.0 mg/mL [16]. Nonspecific BPT with histamine ended when increasing concentrations of histamine achieved the final step of 2 mg/mL histamine or when the cumulative histamine concentration reached 3.8–4.0 mg/mL [17, 18]. The test was interrupted and was considered positive if the spirometric parameter FEV1 had decreased by 20% („cut off") referring to the basic values, and the IOS was positive („cut off") if there was an increase in Rrs5 by 40% or Fres by 35%. Exact consumption of histamine which led to decrease of FEV1 by 20% (PC20) was calculated on a straight line formula. Reports for BPT were originally designed to monitor all the analyzed parameters [19].

All statistical calculations were done by using commercial statistical software Statistica 7.0 StatSoft. Descriptive statistics included conventional parameters for assessing the data of central tendency (mean and median), as well as parameters for evaluation of group variability [standard deviation (SD), range, 95% confidence limits]. The distribution of some characteristics was presented as frequencies. The difference between the distribution characteristics of the group was checked using the χ^2 test. For comparison of lung function parameters between groups, Student's *t*-test was used. To assess the strength of the relationship between various parameters, the Pearson's coefficient of correlation was used. A statistically significant difference was considered in the case of $p < 0.05$, moderately significant in the case of $p < 0.01$ and highly statistically significant if $p < 0.001$.

Results

The study included 81 respondents subjected to nonspecific BCT with histamine. Out of the total number of respondents, 50.5% were men, and their average age was 5.7 ± 5.7 years (Table 1). Allergy testing showed that 55.1% of respondents were positive to mixture of allergens, 25.1% were positive to indoor allergens and 19.7% had pollen allergy. Out of the total number of subjects with AR, 56 (58.9%) had a positive BPT and proven bronchial hyperreactivity, while 25 (41.1%) had a negative BCT. Average consumption of histamine in the group with proven BHR was 1.530 mg/mL (Table 1), whereas in the group with negative BPT it was 3.949 mg/mL on average.

Table 1

Patients (n = 81) characteristics and basic measurements of lung function

Variable	$\bar{x}$ ± SD
Gender, male/female (%)	50.5 ± 49.5
Age, years	25.7 ± 5.7
PC20 mg/mL	1.530 ± 1.21
Zrs5 (%)	117.31 ± 40.17
Rrs5 (%)	112.04 ± 39.13
Rrs20 (%)	111.53 ± 4.09
Rrs5-Rrs20a	0.050 ± 0.042
Xrs5 - kPa/(L/s)	-0.10 ± 0.03
Fres - kPa/(L/s)	10.94 ± 3.00
AX - kPa/(L/s)	0.25 ± 0.16
FVC (%)	106.18 ± 12.16
FEV1 (%)	105.71 ± 15.45
FEV1/FVC (%)	86.21 ± 5.92
FEF50 (%)	95.95 ± 19.26
FEF25/75 (%)	98.13 ± 22.02

PC20 – A 20% reduction in the forced expiratory volume in one second (FEV1); Zrs – total respiratory impedence; Rrs – respiratory system resistance; Xrs – respiratory system reactance; Fres – resonant frequency; AX – asthma index; FVC – forced vital capacity; FEF – forced expiratory flow; $\bar{x}$ – mean value; SD – standard deviation.

Table 2 presents basic measurement values of the spirometry and the IOS paremeters in patients with (the group 1) and without BHR (the group 2). The differences between the value of the spirometry and IOS parameters values in the groups 1 and 2 were not statistically significant except those of FEF50 and FEF25/75.

Table 3 shows the mean values and standard deviations of differences between values of all the spirometry and IOS paramaters monitored in the groups 1 and 2 and determined before and after BCT. It was noted that the mean values of changes in the group 1 were even two times higher than those in the group 2. Table 4 shows the correlations between parameters measured before and after provocation test performed in the group 1 and 2. There was a significant correlation within the group 1 between the value of PC20 and ΔFEV1 (r = 0.41) (Table 5).

Table 2

Lung function in allergic rhinitis (AR) patients with and without bronchial hyperresponsiveness (BHR) – basic measurement

Variable	Group 1 (n = 56)	Group 2 (n = 25)	*p*
	x̄ ± SD	x̄ ± SD	
Zrs5 (%)	121.53 ± 46.46	107.87 ± 17.23	0.158671
Rrs5 (%)	116.04 ± 45.26	103.08 ± 17.01	0.170183
Rrs20 (%)	115.44 ± 39.09	102.77 ± 16.01	0.122977
Rrs5-Rrs20a	0.052 ± 0.044	0.046 ± 0.037	0.586672
Xrs5	-0.10 ± 0.03	-0.10 ± 0.02	0.974030
Fres	11.04 ± 3.14	10.70 ± 2.72	0.638597
AX	0.26 ± 0.16	0.24 ± 0.15	0.725618
FVC (%)	104.86 ± 11.54	109.14 ± 13.22	0.122134
FEV1 (%)	105.58 ± 10.64	106.02 ± 23.15	0.907481
FEV1/FVC (%)	86.26 ± 5.71	86.08 ± 6.48	0.898740
FEF50 (%)	92.61 ± 17.56	103.06 ± 21.30	0.025397*
FEF25/75 (%)	94.81 ± 20.89	105.56 ± 23.07	0.041658*

***p* < 0.05 is statistically significant. Group 1 – patients with BHR; Group 2 – patients without BHR.**
For other abbreviations see under the Table 1.

Table 3

Changes of spirometry and impulse oscilometry (IOS) parameters in the group with and without bronchial hyperresponsiveness (BHR)

Changes (%)	AR with BHR (n = 56)	AR without BHR (n = 25)	*p*
	x̄ ± SD	x̄ ± SD	
ΔZrs5	94.51 ± 52.73	61.89 ± 45.04	0.008854
ΔRrs5	88.15 ± 45.92	59.98 ± 41.14	0.010255
ΔRrs20	43.12 ± 30.50	32.11 ± 29.41	0.133096
ΔRrs5-R20	45.29 ± 29.60	27.87 ± 29.85	0.016929
ΔXrs5	141.51 ± 119.67	88.63 ± 96.55	0.055577
ΔFres	111.98 ± 65.14	75.09 ± 52.17	0.014710
ΔAX	819.69 ± 734.43	424.87 ± 449.23	0.015130
ΔFVC	-13.34 ± 8.26	-2.86 ± 4.68	0.000000
ΔFEV1	-25.66 ± 6.44	-8.41 ± 6.26	0.000000
ΔFEF50	-44.00 ± 8.91	-23.24 ± 14.70	0.000000
ΔFEF25/75	-44.4571 ± 9.86	-20.2140 ± 19.15	0.000000

For other abbreviations see under the Table 1.
AR – allergic rhinitis patients.

Table 4

Correlation between basic measurements of lung function and changes in FEV1 after BCT in the groups 1and 2

Measurement of	Group I (n = 56)				Group II (n = 25)			
FEV1	Rrs5	Xrs5	Fres	AX	Rrs5	Xrs5	Fres	AX
Basic	-0.02	0.27	-0.32	-0.35	-0.06	0.01	-0.24	-0.01
After BCT* (ΔFEV1)	-0.04	-0.07	-0.10	-0.16	-0.62	-0.51	-0.55	-0.55

*** BCT – Bronchial challenge testing; Group 1 – patients with bronchial hyperresponsiveness (BHR); Group 2 – patients without BHR.**
For other abbreviations see under the Table 1.

Table 5

Pearson's correlation coefficient between PC20 and parameters of the spirometry and IOS

Parameters	Pearson's correlation coefficient
ΔRrs5	0.14
ΔFres	0.10
ΔAX	0.06
ΔFEV1	0.41

IOS – impulse oscillometry.
For other abbreviations see under the Table 1.

Parameter Rrs5, as a marker of BHR in patients with AR showed a sensitivity of 82.14% and specificity of 36.0%. The positive and predictive values of Rrs5 were 74.19%, and 47.37%, respectively. Parameter Fres in proving BHR in patients with AR, showed sensitivity of 85.7% and specificity of 28%. The positive and negative predictive values of Fres were 72.73% and 46.67%, respectively (Table 6).

Table 6

Sensitivity and specificity of Rrs5/Fres in the bronchial challenge testing (BCT)

Parameters	ΔRrs5 (%)		ΔRrs5 (%)	
	Mean	(95% confidence interval)	Mean	(95% confidence interval)
Sensitivity	82.14	(72.16 – 92.12)	85.71	(76.60 – 94.83)
Specificity	36.00	(17.28 – 54.72)	28.00	(10.49 – 45.51)
Total accuracy	67.90	(57.79 – 78.02)	67.90	(57.79 – 78.02)
Positive predictive values	74.19	(63.36 – 85.03)	72.73	(62.04 – 83.42)
Negative predictive values	47.37	(25.03 – 69.71)	46.67	(21.55 – 71.79)

Rrs5/Fres – respiratory system resistance/resonant frequency.

Discussion

AR represents a prime risk factor for asthma, according to the ARIA guidelines [1, 7, 20]. Particular attention is paid to patients with AR and confirmed BHR, but without cardinal symptoms indicating asthma.

In everyday clinical practice the only method that reached the value of spirometry, a „gold standard“ in diagnostics of respiratory pathology, is the IOS [8].

In the scientific literature in Serbia, and some other countries, there are a few papers dealing with estimation of BHR by the IOS in patients with persistent RA [21, 22].

In our study nonspecific BPT with histamine revealed that 58.9% patients with AR had asymptomatic BHR (the group 1). Among patients who reacted to the provocative concentrations between 1 and 16 mg/mL of histamine that led to a drop in FEV1 of 20% (PC20), but have no symptoms of asthma, there were several subgroups: 1) patients with mild intermittent asthma who felt no bad asthma symptoms; 2) patients who did not experience the qualm in the chest as abnormal after exertion or provocation test; 3) patients who never had experience with effort or inhalation of harmful substances; 4) patients with mild degree of BHR, which was demonstrated after viral upper respiratory tract infections or smoking; 5) asymptomatic patients with asthma that would become clinically manifested in the future [15, 23]. Heppt et al. [24] reported that BHR was present in 10% to 50% of patients with AR. Zhong et al. [25] showed that in about 1.5% and 45% of asymptomatic people with AR and proven BHR asthma could develop in the future, in a period of 2–3 years. The group of Australian authors established BHR in 11.4% of random sample of the adult population in Australia [26]. Valdesoiro et al. [27] demonstrated that patients with AR without asthma symptoms and with confirmed BHR may have subclinical inflammation. They processed a total of 135 patients with AR, out of which BPT was positive in 24% respondents. Cuttitta et al. [28] investigated the prevalence of BHR in a sample of nonasthmatic children with AR by metacholin test; there were 31 (61%) children without, and 6 (20%) with evidence of BHR. Riccioni et al. [29] presented that 54.5% subjects with perennial AR, demonstrated BHR [29]. Gaur et al. [30] showed that inhaled allergens were predictors of BHR in 32 adult patients with AR and proved the presence of asymptomatic BHR in 81.2% of subjects [30]. Presented studies shows different frequency of BHR in subjects with AR.

Analysis of basic spirometric parameters showed that their mean values were far above the normal ones. In the paper of the Korean authors [31] there were seen similar mean values of basic spirometric parameters in the asthmatic patients.

Analysis of the basic IOS parameters showed similarity in the mean values between the groups 1 and 2. Mean values of the IOS parameters had a high degree of variability indicating broad range between the maximum and minimum values. This is one of the key factors why this method did not become a standardized test for estimating lung function. One of the studies that investigated the variability in the measurement of respiratory impedance were made by Goldman et al. [32] They showed a daily variability in the parameters Rrs5, Rrs5-Rrs15 (difference of resistance at 5 Hz and 15 Hz) and AX in patients with asthma. According to constructor's recommendation [8] for the threshold values for Rrs5 over 150% of the predicted values, Rrs20 over 150% of the predicted values and Xrs5 over -0.15 kPa/(l/s) (the difference between the active and predicted value) separate normal from abnormal findings. In addition to all of spirometry parameters which were far above the limits of normal values in the group 1, there were 5 patients with abnormal values of Rrs5 and 6 patients with abnormal values of Xrs5, which indicates that the IOS, unlike spirometry, can establish changes in the airways before bronchodynamic tests and indicate inflammation in the airway.

After testing the bronchial response to histamine patients were allocated to the groups of patients with and without BHR. The group with BHR had high mean values of the IOS parameters that were accompanied by high values of SD, which was especially pronounced for ΔAX. In the group 2, high mean values of the IOS parameters were also shown. There were no significant differences in values of the IOS and spirometry parameters between the two groups. Within the group with positive BHR there was no significant correlation between ΔFEV1 and parameters of the IOS, while in the group without evidence of BHR a significant correlation between ΔFEV1 and monitored parameters of the IOS was shown. Nonspecific BPT with histamine was positive with an average expenditure of the provocation substance of 1,530 mg/mL to achieve PC20, while in the group with negative test the mean value of the consumption of histamine was 3,949 mg/mL. Similar consumption of

histamine in provocation tests was shown in a study of Skiepko et al. [33].

The sensitivity and specificity of the IOS as a new method gives hope that in the future it can become the conventional method for estimating lung function and a great support to other spirometric methods. Based on the study of Marotta et al. [34] and the proposal of constructor Hans Jurgen Smith, we took „cut off" value for Rrs5 to demonstrate BHR [8]. In our study, sensitivity of the method for confirmation of BHR in patients with AR for Rrs5 was 82.14% and the specificity was 36.0%, and for Fres the sensitivity was 85.7% and the specificity 28%. The high sensitivity of both parameters indicates that you really can prove BHR in the respectable percentage of patients with AR. Schulze et al. [35] evaluated the spirometry and IOS during methacholine challenge test, and showed an increase of Rrs5 to 45.2% with a reduction in FEV1 of 20% in 70–80% of patients with BHR detected by the IOS. During BCT an increase in Rrs5 preceded the decrease in FEV1 of 20%. Komarow et al. [22] examined the sensitivity of the IOS in relation to the spirometry test in children of average age of 7 years with and without asthma and demonstrated that resistance at 5 Hz had a high sensitivity (0.73) and low specificity (0.34), and the reactance at 5 Hz, had a low sensitivity (0.59) and specificity (0.31) for Xrs5, which is similar to our results. Shin et al. [36] studied the bronchodilatory response among preschool children with asthma and healthy children, and demonstrated high sensitivity (0.92) and poor specificity (0.52) of Rrs5 in comparison with FEV1.

Conclusion

The study demonstrated a high prevalence of BHR in the group of patients with persistent AR, poor correlation with spirometric parameters in the group of patients with BHR, as well as high sensitivity and low specificity of IOS in detection of early changes in the airways.

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