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A comparison of Spirometry Versus Impulse Oscillometry in Patients with Asthma Based on Asthma Severity

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ABSTRACT

Measuring the performance of small airways dysfunction is challenging due to their relative inaccessibility with conventional methods. In recent years, spirometry and impulse osillometric (IOS) methods have been widely used for their evaluation. The aim of this study was to investigate the relationship between spirometric parameters and IOS in newly diagnosed asthma (NDA) patients.

In this cross-sectional study, 100 NDA patients who referred to the allergy Clinic of Masih Daneshvari Hospital between 2021 and 2023 were enrolled. IOS and spirometry tests were performed for all patients. Spirometry measures included forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC, and forced expiratory flow (FEF25-75). IOS criteria included R5%, R20%, R5-R20%, X5%, Ax% and FRES. The relationship between spirometry and IOS parameters was evaluated.

The mean age was 22.6±9.5 years. None of the 2 techniques had a significant relationship with disease severity. FVC, FEV1/FVC and FEF25-75 indices had a significant positive correlation with all other IOS indices except for Ax. In the comparison of FEF25-75 parameter in spirometry, 4 IOS indices including R5, R20, R5-R20 and X5 had appropriate sensitivity and specificity for predicting asthma. In the comparison of FEF25-75 parameter in spirometry, 4 IOS indices including R5, R20, R5-R20 and X5 had appropriate sensitivity and specificity for predicting asthma. The sensitivity and specificity of R5 for asthma diagnosis were 0.85 and 0.73, respectively.

Further multicenter studies with larger sample sizes are recommended to confirm these results.

Keywords: Asthma; Impulse osillometry; Spirometry

INTRODUCTION

Asthma is one of the most prevalent respiratory diseases worldwide. In this disease, the airways become narrow and swollen and may even produce excess mucus. This condition can make breathing difficult and cause coughing, wheezing, and shortness of breath.[1,2]

In obstructive lung diseases, especially asthma, pulmonary function evaluation is particularly important in diagnosis, disease severity, prognosis, and evaluation of response to treatment[3].

In general, there are 2 methods for evaluating airway obstruction, which include spirometry and impulse oscillometry (IOS).[4]

Spirometry is the most common lung function test

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and is considered as the gold standard diagnostic test for asthma and chronic obstructive pulmonary disease.[5] Since spirometry requires activity and requires continuous training, younger children, elderly people, patients with a severe advanced respiratory disease, or those with cognitive or neurological disorders cannot perform spirometry.[6-8]

IOS was introduced as an alternative method for conventional pulmonary function testing.[9] In this method, only the fluctuations of the flow pressure in the mouth affect breathing, so that the resistance and reaction of the respiratory system can be measured at different oscillation frequencies.[4,10] The main advantage of IOS compared to spirometry is its ease, its ability to be performed with simple breathing, requiring less cooperation and independent of the patient's effort.[11-13]

Various studies have shown that IOS can be used as an alternative to routine pulmonary function tests to support the diagnosis and monitoring of asthma when forced exhalation maneuvers are contraindicated.[14,15] Measuring the performance of small airways faces many challenges due to the relative lack of access.[16]

Due to the lack of studies in Iran, the present study was conducted with the aim of investigating the relationship between spirometry and IOS parameters with asthma severity in patients aged 12 to 40 years.

MATERIALS AND METHODS

In this cross-sectional study, 100 newly diagnosed asthma patients, aged 12 to 40 years, referred to the Allergy and Pulmonary Clinic of Masih Daneshvari Hospital affiliated to Shahid Beheshti University of Medical Sciences, Iran between 2021 and 2023 were enrolled. Sampling was done in a convenient way.

Inclusion criteria were a definitive diagnosis of mild to severe asthma without receiving any medical treatment for asthma, aged 12 to 40 years, and consent to participate in the study.

Exclusion criteria were evidence of respiratory infection in the last 1 month, a history of exacerbation of clinical symptoms of asthma in the last one month, heart disease, any lung disease other than asthma, receiving medical treatment for respiratory diseases, and inability to perform pulmonary function tests.

Asthma severity was classified as follows based on the Expert Panel Report 3 (EPR3) criteria. Both spirometry and IOS tests were performed for all patients. Spirometry test was performed using MasterScreen according to American Thoracic Society standards[17]. Spirometry criteria included forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC and forced expiratory flow (FEF25-75). Also, for each patient, the IOS test and its related parameters (R5%, R20%, R5-R20%, X5% Ax%, and FRES) were recorded. Then, the spirometry and IOS parameters were compared.

The protocol of the study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences with the IR.SBMU.MSP.REC.1402.142.

Statistical Analysis

Statistical analysis was performed by SPSS software Version 22. Mean±SD and number (percentage) indicate quantitative and qualitative variables, respectively. Kolmogorov-Smirnov and Shapiro-Wilk tests were used for normality distribution. Pearson's test was used to evaluate the correlation. $p<0.05$ was considered statistically significant.

RESULTS

The mean age of the patients was 22.6±9.5 years. Of the 100 patients studied, 65% were female. The mean of body mass index was 25.4±4.4 kg/m^2. Rhinitis was reported as the most common symptom with 66%. Gastroesophageal reflux disease (GERD) and sinusitis were observed in 17% and 37% of patients, respectively. Based on disease severity, mild, moderate, and severe types of disease were reported in 42%, 52%, and 6% of patients, respectively. The demographic and clinical characteristics of all patients are provided in Table 1.

The mean percentage of FEV1 and FVC were 94.5±13.1 and 90.3±16.3, respectively. Moreover, the mean percentage of forced expiratory flow 25–75 (FEF25-75) was 125.08±75.5. The ratio of FEV1 to FVC was 10.9.9±80.6. The mean of resistance at 5 Hz (R5) and resistance at 20 Hz (R20) were 121.48±39.6 and 119.1±34.3 kPa/Ls, respectively. Other IOS parameters are given in Table 2.

Based on the results of the correlation between the parameters and the severity of the disease, although the correlation of the IOS indices was slightly higher than the spirometric parameters, no significant correlation was observed between the indices of any of the methods with the severity of the disease, in fact, clinically, IOS parameters were more sensitive to airway changes than spirometric parameters. More details are provided in Table 3.

Table 1. Demographic and clinical characteristics of all patients (n=10)

Variable		Result
Age (year), mean±SD		22.6±9.5
Gender	Female	65 (65%)
	Male	35 (35%)
BMI (Kg/m2), mean±SD		25.4±4.4
Rhinits, n (%)		66(66%)
Sinusitis, n (%)		37(37%)
GERD, n (%)		17(17%)
Severity, n (%)	Mild	42 (42%)
	Moderate	52 (52%)
	Severe	6 (6%)

BMI: body mass index; GERD: gastroesophageal reflux disease

Table 2. Spirometry and impulse oscillometry parameters in all patients

Variable	Normal range	Range	Result (mean±SD)
FEV1 (L)	≥80%	62–125	94.5±13.1
FVC (L)	≥80%	46–120	90.3±16.3
FEV25-75 (L/S)	≥60%	18–130	125.08±75.5
FEV1/FVC (%)	≥70%	54–110	10.9.9±80.6
R5 (kPa/L s)	<150	67–311	121.48±39.6
R20 (kPa/Ls)	<150	46–296	119.1±34.3
R5-R20 (kPa/Ls)	<150	20–917	147.4±119.2
X5 (kPa/Ls)	<150	43–2888	649.9±602.2
Ax (kPa/L)	<150	85–7700	835.1±1407.2
FRES (Hz)	7-14	28–40	15.1±4.7

FEV1: forced expiratory volume in 1 second; FVC: forced vital capacity; FEF25-75%: forced expiratory flow 25–75; R5: resistance at 5 Hz; R20: resistance at 20 Hz; X5: reactance at 5 Hz; AX: area of reactance.

The results of linear regression showed that the FVC indices in spirometry, except for Ax, had a significant positive correlation with all other IOS indices. R5 index had the highest correlation (r=0.05, *p*=0.001). Moreover, except Ax and FRES, FEV1 had a significant correlation with all other indexes of IOS. FEV1/FVC index and FEF25-75 in spirometry had a significant correlation with all other indices of IOS except for Ax (Figure1). The correlation between indices in 2 methods is shown in Table 4.

The 3 indices R5, R20 and R5-R20 had appropriate sensitivity and specificity for predicting asthma. The sensitivity and specificity of R5 were 0.69 and 0.6, respectively.

The 4 indices R5, R20, R5-R20 and X5 had appropriate sensitivity and characteristics for predicting asthma. The sensitivity and specificity of R5 were 0.85 and 0.73, respectively.

Table 3. Correlation of spirometry and impulse oscillometry parameters with disease severity

Variable	Severity	
	r	*p*
Spirometry parameters		
FVC(L)	0.15	0.11
FEV(L)	0.18	0.08
FEV1/FVC (%)	0.18	0.087
FEF(L/S)	0.13	0.16
impulse oscillometry parameters		
kPa/Ls) (%R5	−0.2	0.09
R20% (kPa/Ls)	−0.22	0.059
R5-R20% (kPa/Ls)	−0.23	0.08
(kPa/L s) X5	−0.24	0.05
Ax (kPa/L)	−0.09	0.32
FRES (Hz)	−0.1	0.22

Table 4. Correlation of spirometric parameters with impulse oscillometry based on linear regression

	Variable	FEF25-75 (L/S)	FEV1/FVC (%)	FEV (L)	FVC (L)
R5	B	−0.5	−0.39	−0.35	−0.47
	p	0.001	0.001	0.001	0.001
R20	B	−0.45	−0.35	−0.28	−0.43
	p	0.006	0.008	0.008	0.001
R5-R20	B	−0.34	−0.27	−0.29	−0.3
	p	0.008	0.009	0.009	0.003
X5	B	−0.29	−0.29	−0.21	−0.22
	p	0.01	0.008	0.032	0.011
AX	B	−0.09	−0.09	−0.08	−0.07
	p	0.35	0.39	0.8	0.85
FRES (Hz)	B	−0.22	−0.15	−0.22	−0.27
	p	0.035	0.13	0.038	0.006

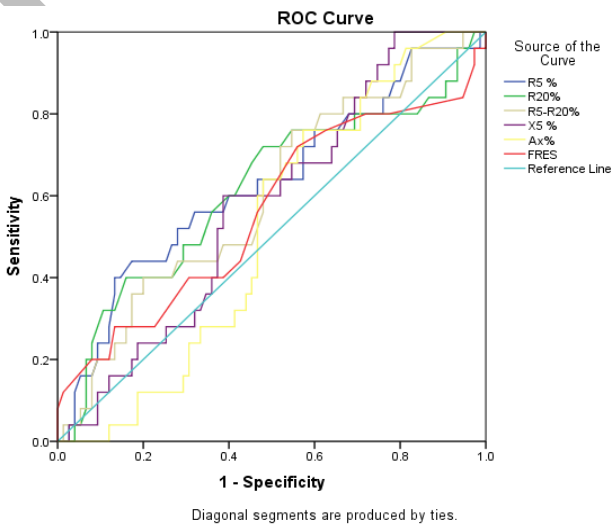

Figure 1. Diagram of diagnostic power of impulse oscillometry indices compared to FEV1/FVC

DISCUSSION

Despite the importance of diagnosing small airway disease, measuring small airway function is challenging due to their relative inaccessibility with conventional methods. In recent years, spirometry and IOS methods have been widely used to evaluate small-airway dysfunction (SAD).[18,19]

The accuracy and performance of spirometric and IOS parameters for evaluating SAD based on different maneuvers is still being discussed. Therefore, considering the importance of this issue, this study aims to investigate the relationship between spirometric parameters and IOS on the diagnosis of asthma and also the diagnosis of its severity in 100 patients with asthma.

Similar to the results of our study, Palacios et al evaluated the correlation of IOS with spirometry parameters and asthma control in an adult population and showed that the accuracy of both IOS and spirometry techniques for differentiating disease severity was low and close to 60%. They showed that IOS parameters are more sensitive to changes in small airways than spirometry, although these changes were not significant. In addition, IOS values showed a good correlation with spirometric values.[20]

In another study, Pisi et al evaluated spirometric parameters and IOS in patients with asthma and showed that in patients with mild to moderate asthma, spirometric and IOS indicators complement each other in the diagnosis of SAD. Also, IOS was more sensitive to changes in small airways than spirometry.[16]

Considering the correlation between some spirometry and oscillometry parameters, IOS can be used if the patient is unable to perform the spirometry test. One of the limitations of the study was the small sample size of patients with cystic fibrosis and the distribution of patients throughout the country. One of the strong points of the study is that the spirometry and oscillometry tests were performed by a pulmonologist with great accuracy, and the patient was fully trained before the test. It is suggested that more multicenter studies with higher sample size should be conducted in order to investigate the relationship between Impulse Oscillometry and spirometry parameters in children with cystic fibrosis.

STATEMENT OF ETHICS

The study was approved by the Medical Ethical Committee of Shahid Beheshti University of Medical Sciences (Ethics code: IR.SBMU.MSP.REC.1403.478).

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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DATA AVAILABILITY

The dataset presented in the study is available on request from the corresponding author during submission or after its publication. The data are not publicly available due to privacy of patients.

AI ASSISTANCE DISCLOSURE

If applicable, list any artificial intelligence (AI) tools used in preparing this manuscript.

REFERENCES

1. Hough KP, Curtiss ML, Blain TJ, Liu R-M, Trevor J, Deshane JS, et al. Airway remodeling in asthma. Front Med. 2020;7:191.
2. Viegi G, Maio S, Fasola S, Baldacci S. Global burden of chronic respiratory diseases. J Aerosol Med Pulm Drug Deliv. 2020;33(4):171-7.
3. Fazlollahi MR, Najmi M, Fallahnezhad M, Sabetkish N, Kazemnejad A, Bidad K, et al. The prevalence of asthma in Iranian adults: The first national survey and the most recent updates. Clin Resp J. 2018;12(5):1872-81.
4. Desiraju K, Agrawal A. Impulse oscillometry: The state-of-art for lung function testing. Lung India. 2016;33(4):410-6.
5. Bailey KL. The importance of the assessment of pulmonary function in COPD. Med Clin North Am. 2012;96(4):745-52.
6. Beydon N, Davis SD, Lombardi E, Allen JL, Arets HG, Aurora P, et al. An official American Thoracic

Society/European Respiratory Society statement: pulmonary function testing in preschool children. Am J Respir Crit Care Med. 2007;175(12):1304-45.
7. Barks L, Davenport P. Wheelchair components and pulmonary function in children with cerebral palsy. Assistive Technol. 2012;24(2):78-86.
8. Lipworth B, Manoharan A, Anderson W. Unlocking the quiet zone: the small airway asthma phenotype. The Lancet Resp Med. 2014;2(6):497-506.
9. Youssef HA, Shalaby A, Kaddah S, Selim S, Saad M. Impulse oscillometry as an alternative modality to the conventional pulmonary function tests in chronic obstructive pulmonary disease. Egyp J Chest Dis Tubercul. 2017;66(3):395-9.
10. Komarow HD, Myles IA, Uzzaman A, Metcalfe DD. Impulse oscillometry in the evaluation of diseases of the airways in children. Ann Allergy Asthma Immunol. 2011;106(3):191-9.
11. Komarow HD, Myles IA, Uzzaman A, Metcalfe DD. Impulse oscillometry in the evaluation of diseases of the airways in children. Ann Allergy Asthma Immunol. 2011;106(3):191-9.
12. Desai U, Joshi JM. Impulse oscillometry. Adv Resp Med. 2019;87(4):235-8.
13. Nikkhah M, Amra B, Eshaghian A, Fardad S, Asadian A, Roshanzamir T, et al. Comparison of impulse osillometry system and spirometry for diagnosis of obstructive lung disorders. Tanaffos. 2011;10(1):19.
14. Song TW, Kim KW, Kim ES, Kim KE, Sohn MH. Correlation between spirometry and impulse oscillometry in children with asthma. Acta Paediatrica. 2008;97(1):51-4.
15. Jordon LH, Gore RB, Rusk RA, Knox-Brown B, Marciniak SJ. The role of impulse oscillometry in the management of asthma when forced expiratory maneuvers are contraindicated: Case series and literature review. J Asthma. 2022;59(8):1577-83.
16. Pisi R, Aiello M, Frizzelli A, Feci D, Aredano I, Manari G, et al. Detection of Small Airway Dysfunction in Asthmatic Patients by Spirometry and Impulse Oscillometry System. Resp Int Rev Thoracic Dis. 2023;102(7):487-94.
17. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisationt of spirometry. Europ Resp J. 2005;26(2):319-38.
18. Cottini M, Bondi B, Bagnasco D, Braido F, Passalacqua G, Licini A, et al. Impulse oscillometry defined small airway dysfunction in asthmatic patients with normal spirometry: Prevalence, clinical associations, and impact on asthma control. Resp Med. 2023;218:107391.
19. Gupta S, Mukherjee A, Gupta S, Jat KR, Sankar J, Lodha R, et al. Impulse oscillometry (IOS) for detection of exercise induced bronchoconstriction in children with asthma ages 6–15 years. J Asthma. 2023;60(7):1336-46.
20. Díaz Palacios M, Hervás Marín D, Giner Valero A, Colomer Hernández N, Torán Barona C, Hernández Fernández de Rojas D. Correlation between impulse oscillometry parameters and asthma control in an adult population. J Asthma Allergy. 2019;12:195-203.