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Research Article

Comparative Study Of Impulse Oscillometry And Spirometry In Patients With Asthma Visiting A Tertiary Health Care Hospital

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ABSTRACT

Introduction
The mechanical properties of lungs play a crucial role in respiratory health. However, these properties are disrupted in diseased states, such as asthma, which influence airflow regulation. Techniques such as spirometry are commonly used to assess the mechanical properties of the airways. In this regard, impulse oscillometry (IOS) is increasingly being recognized as a non-invasive technique. This study aimed to evaluate the diagnostic and prognostic utility of IOS in patients with asthma, as well as to explore the correlation between IOS and spirometry variables.

Material and methods This cross-sectional study included 50 patients with asthma, who were recruited from the Department of Respiratory Medicine at Sri Lalithambigai Medical College and Hospital from February to March 2023. The patients met the criteria of the ethical committee. Patients with physician-diagnosed asthma and those who discontinued the use of short-acting and long-acting bronchodilators and sustained-release theophylline 6 h, 12 h, and 24 h before the test, respectively, were included in the study. Patients with exacerbated asthma in the 3 months preceding the study and those with other apparent respiratory illnesses were excluded. All the patients had their spirometry (FVC, FEV1, and FEV1/FVC) and IOS (R5, R20, and X5) measures recorded. The IOS results were compared to those obtained by spirometry.

Results The average age of the participants in our study was 46 years, with a standard deviation of 15 years. Male patients comprised 67% of the participants. Among patients with asthma, the sensitivity for R20 (the most indicative value of IOS measurements in the asthma group) was 82%. We observed a correlation between the IOS measures R5, R20, and X5 with the spirometry measure FEV1 among patients with asthma. Additionally, R5 and R20 demonstrated a significant correlation with FVC in patients with asthma.

Conclusion As significant correlations were observed between the IOS and spirometry measures, we infer that IOS can be used as a complementary test to spirometry for long-term follow-up and could be clinically beneficial.

Categories Respiratory medicine, diagnosis and testing

Keywords Asthma, impulse oscillometry, spirometry, diagnosis, lung function testing

Introduction

Asthma exhibits a considerable influence on airflow regulation in the respiratory system. The inflammation in asthma manifests as various symptoms, including wheezing, shortness of breath, coughing, and chest

tightness. Asthma can vary in severity and can be triggered by different factors, including allergens, exercise, respiratory infections, and environmental irritants. While small airway remodeling plays a significant role in asthma, it is only one aspect of its complex pathophysiology [1]. Assessment of lung function is important in the diagnosis of asthma and in monitoring disease progression as well as the patients' response to therapy. The mechanical properties of lungs are commonly assessed using techniques, such as spirometry, pulmonary function tests, and lung volume measurements [2].

Impulse oscillometry (IOS) is increasingly being recognized as a non-invasive method for assessing the mechanical properties of lungs [3]. During an IOS test, the patient breathes through a mouthpiece connected to a device that generates small pressure oscillations at different frequencies. These oscillations cause the patient's airways to vibrate, and the device measures the resulting changes in pressure and flow. By analyzing these measurements, information about the resistance and stiffness of the airways can be obtained [4]. Tidal breathing analysis is often performed using specialized devices called pulmonary function testing equipment or spirometers. These instruments measure the flow of air and pressure changes during breathing, allowing for the calculation of respiratory impedance components. The obtained data can be used to assess lung function, detect abnormalities, and guide appropriate treatment strategies [5]. One significant advantage of IOS is that it relies on measuring lung parameters during breathing at rest, meaning that dedicated efforts from the patient are not necessary. This makes IOS particularly useful in situations where patients, such as young children, the elderly, or those with cognitive impairments, may have difficulty performing other pulmonary function tests, such as spirometry, which require active participation. A few studies suggest that IOS and spirometry provide complementary information about lung function in COPD and asthma [6–9]. Spirometry and IOS may capture different aspects of airway mechanics and could be useful in assessing different aspects of these diseases. For example, spirometry primarily assesses airflow limitation, while IOS parameters may provide additional information about small airway function and peripheral airway resistance [10–13].

Therefore, the aims of this study were to explore the potential of IOS in the diagnosis and evaluation of patients with asthma, to assess the correlation between the lung parameters obtained through IOS with those obtained using spirometry, and to evaluate the repeatability and the long-term variabilities of the parameters obtained through IOS.

Materials and methods

A prospective, cross-sectional study involving 50 patients with asthma was conducted. The participants were recruited from the Department of Respiratory Medicine, Sri Lalithambigai Medical College and Hospital, from February to March, 2023. The ethics committee of Sri Lalithambigai Medical College and Hospital approved the study protocol. All methods, including pulmonary function tests and IOS, were carried out according to the relevant guidelines. All the patients were in stable condition. Patients with physician-diagnosed asthma, those able to perform spirometry, and those who discontinued short-acting bronchodilator inhalers, long-acting bronchodilators, and sustained-release theophylline 6 h, 12 h, and 24 h before spirometry, respectively, were included in the study. Patients with asthma exacerbation in the last 3 months, those with other respiratory diseases, diabetes, ischemic heart disease, cystic fibrosis, tuberculosis, bronchomalacia, vocal cord dysfunction, tracheoesophageal fistula, hypersensitivity pneumonitis, or chronic liver disease, and those under treatment with ACE inhibitors/alpha-blockers, which could induce chronic cough, were excluded. By consolidating the medical history and information from clinical examination, chest radiograph, spirometry, and IOS measurements, healthcare providers can thoroughly understand the patient's respiratory health, and this facilitates informed decisions regarding the diagnosis, treatment, and management of respiratory conditions. The spirometry parameters measured included forced expiratory volume at first second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, and forced expiratory flow (FEF 25-75%). Medical history, physical examination, and GINA guidelines were used as the basis for asthma diagnosis in all the patients. By dividing the study participants into these two groups, factors related to asthma control, such as medication effectiveness, lifestyle factors, or comorbidities, can be analyzed, to potentially improve patient care. A set of five questions was prepared; if a patient obtained a total score >20 points on the ACT, their asthma was considered controlled. On the other hand, if the total score was 19 or less, their asthma was categorized as uncontrolled. Notably, the ACT scoring system may vary based on the specific guidelines or healthcare provider; however, the general concept of categorizing asthma severity as controlled and uncontrolled remains consistent.

IOS maneuver was performed according to the recommended protocol, using a Master lab-IOS Unit (Master Screen IOS 2001, version 4.5; Erich Jaeger GmbH, Hochberg, Germany). The system was calibrated for volume using a 3 L syringe, to ensure accurate measurements. The syringe was used to deliver a known volume of air into the system, allowing the IOS device to establish a reference point for volume measurement. The patient was advised to maintain tidal breathing, which is the default breathing pattern at rest or during light physical activity. This breathing pattern requires minimal energy expenditure. During IOS measurements, the patient's hands are placed over their cheeks and a nasal clip is used to occlude the nares, to avoid relaxation of the cheeks during the process. Parameters related to pulmonary function, which can provide valuable information about respiratory function and potential obstructions in the airways, were

measured. These include R5 (respiratory resistance at 5 Hz), X5 (respiratory reactance at 5 Hz), and Ax (reactance area) from X5 to Fres (resonant frequency). The parameter R5–20 is calculated by subtracting R20 (high-frequency central resistance) from R5, and it represents peripheral airway resistance. Elevated R5–20 suggests peripheral airway obstruction because the pressure wave signal encounters more resistance in the distal lung (R5) than in the proximal region (R20). An abnormal R5–20 value (>0.03 kPa/L) suggests increased total airway resistance, which may be indicative of airway obstruction, whereas a normal X5 value is one that matches the predicted X5 value of 0.15 kPa/L. The normal value of Ax is 0.33 kPa/L.

Statistical analysis

The Shapiro–Wilk test, which is commonly used to statistically assess whether a dataset follows a normal distribution, was utilized to evaluate the normality of the distributions in the dataset. Long-term variability was defined as the standard deviation of the measurements obtained in the first three visits for each patient (SDbv). The coefficient of variation (COV=SDbv/mean) and the intraclass correlation coefficient (ICC; mixed-effects model, absolute agreement, mean of three raters) of the IOS measurements during the three clinic visits were calculated. An ICC value between 0.5 and 0.6 was considered medium repeatability, a value between 0.7 and 0.8 was considered good repeatability, and a value >0.8 was considered very good repeatability. The coefficient of repeatability (COR), defined as twice the standard deviation of the differences between parameters measured during two pairs of consecutive clinic visits from three clinical visits per patient or expressed as a percentage of close to maximal variation (pMV), was also calculated [14, 15]. pMV ranges between 0 and 33%, 33 and 66%, and above 66%, were considered decent, good, and poor repeatabilities, respectively. Age and body mass index (BMI) were analyzed by one-way ANOVA. Wilcoxon Mann–Whitney test was used for data that did not conform to the normality of distributions. The Kruskal–Wallis test was used to compare multiple groups, and the Bonferroni test was used for post-hoc comparison. The relationship between variability (SDbv) and FEV1 as a percentage of predicted (%FEV1) was examined using Spearman's correlation coefficient for nonparametric data. Multiple regression analysis was used to analyze the factors potentially influencing the variability of IOS parameters in stable patients with asthma between long-term clinic visits.

Results

Demographic Characteristics and Global Initiative for Chronic Obstructive Lung Disease (GOLD) Classification

Among the 50 participants in the study, 67% were males. The average age of the participants was 46 years, with a standard deviation of 15 years. Patients with asthma were younger [(49.86±14.26) years] than patients with COPD [(62.68±9.57) years]. The patients were categorized based on the severity of disease into GOLD stage 1 (1 patient), stage 2 (22 patients), stage 3 (31 patients), and stage 4 (19 patients).

Lung Function Test Results

Spirometry: The lung function test results of patients with COPD and those with asthma, obtained through spirometry, are displayed in table 1. Although patients with asthma were younger, spirometry parameters in patients with COPD were lower than those in patients with asthma. Though FEV1 is a common spirometry measure to assess lung function, it may not fully assess the abnormalities in small airways. Therefore, we analyzed lung function using IOS as well.

IOS parameters: IOS parameters, such as R5 and X5, showed a stronger correlation with clinical symptoms than that shown by spirometry.

Correlation of Spirometry and IOS Parameters

The sensitivity for R20 (the most indicative value of IOS measurements in the asthma group) was 82%. A correlation was observed between the IOS measures R5, R20, and X5 with the spirometry measure FEV1 among patients with asthma. Moreover, R5 and R20 were significantly correlated with FVC.

Long-Term Variability of Parameters

A comparison of the long-term variability of IOS parameters with those of spirometry revealed that spirometry parameters had higher variability and lower repeatability than IOS parameters in different GOLD stages. The SDbv of FVC, R5, AX, and X5 were statistically different between the GOLD1-2, GOLD3, and GOLD4 groups. IOS resistance parameters showed higher stability and reproducibility over time than those of the reactance parameters. The IOS measurements were repeatable among different clinical visits with a median time of around 4–6 months between the visits, as indicated by ICC values greater than 0.80 in both asthma and COPD. In contrast, low ICC values were observed for minimum clinically important differences in asthma and COPD. Moreover, a few IOS parameters, such as R5, showed correlations with the percentage of FEV1 in patients with COPD belonging to the GOLD4 category.

Discussion

Spirometry is considered a gold standard method to assess lung function and is the most commonly used technique. However, IOS is increasingly being recognized as a patient-friendly technique, as it utilizes tidal breathing and is relatively effort independent [16]. In this study, we assessed the diagnostic and prognostic utility of IOS in patients with asthma and explored the correlation between IOS and spirometry variables. Our results indicate that IOS parameters show a stronger correlation with clinical symptoms than that shown by spirometry. Moreover, IOS parameters were more repeatable and less variable than those of spirometry.
Several studies have compared the potential of IOS with that of spirometry, in detecting lung function improvement in patients with asthma. Notably, Saadeh et al. reported IOS to be more reliable than spirometry in detecting improvement after therapy, as IOS parameters showed considerable variation in patients before and after treatment with corticosteroids for 3 months, even as spirometry parameters did not demonstrate variations [17]. Similar observations were noted by Mandilwar et al., who reported statistically significant changes in the IOS parameter R5 compared to changes in the spirometry parameter FEV1 after administering a short-acting bronchodilator. The changes in R5 and FEV1 after 3 months showed the same trend, with R5 showing significant changes compared to the changes in FEV1 [18]. Another study involving patients with severe asthma reported the improvement in IOS parameters to be statistically significant, even when no significant improvement in spirometry parameters was detected, after 3 months of follow up. However, in patients with mild-to-moderate asthma, all spirometry and IOS parameters demonstrated significant improvement after the follow up [16]. These observations collectively suggest that IOS can detect changes in airway properties that cannot be detected by spirometry. Additionally, the correlation between IOS and spirometry parameters was analyzed in a study by Palacios et al., who proposed a model to predict spirometry values from those obtained by IOS. Though a good correlation was observed between IOS and spirometry values in general, the spirometry values obtained from this model were overestimated at low values and underestimated at high values [19].

Our study had a larger sample size compared to that of previous research, making its findings more robust. However, a potential limitation was that no correlations were drawn with sex or age in different diseases and GOLD stages. Additionally, the follow-up period was relatively short, and a longer follow-up could provide more insights. Overall, this study indicates that IOS parameters, particularly resistance, display stability and reproducibility over time, making them a valuable adjunct to lung function tests in assessing lung diseases, such as COPD and asthma. The study also highlights the limitations of spirometry in fully assessing small airway abnormalities and suggests that IOS can provide additional valuable information in the clinical evaluation of patients with respiratory conditions.

Conclusions

We demonstrate that resistance parameters measured by IOS exhibit long-term repeatability. This suggests the reliability of IOS for routine lung function testing over an extended period, thereby facilitating disease progression monitoring, disease activity, and treatment response. Notably, IOS does not aim to replace spirometry, as different aspects of lung function are measured in the two tests. Spirometry assesses airflow limitation by measuring FEV1 and FVC, to provide valuable information on obstructive and restrictive lung diseases, whereas, IOS measures respiratory impedance and resistance at various frequencies, providing insights into airway function and peripheral lung properties. However, using IOS to complement spirometry could be clinically beneficial when long-term follow-up is required.

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Table 1: Slopes for tests of lung function assessed using spirometry in the first 12 weeks and from 12 to 48 weeks of treatment

Lung Function	Time	Treatment	Estimate (95% CI)	Probability
FEV1	0–12 weeks	Combination	0.320 (0.201, 0.439)	<0.0001
		Fluticasone	0.596 (0.477, 0.715)	<0.0001
		Montelukast	−0.011(−0.128, 0.107)	0.8589
	12–48 weeks	Combination	−0.028(−0.096, 0.039)	0.4138
		Fluticasone	−0.039 (−0.105, 0.027)	0.2483
		Montelukast	−0.028 −0.094, 0.038)	0.4010
FEV1 /FVC	0–12 weeks	Combination	0.225 (0.135, 0.315)	<0.0001
		Fluticasone	0.375 (0.287, 0.463)	<0.0001
		Montelukast	0.015 (−0.071, 0.101)	0.7323
	12–48 weeks	Combination	−0.036 (−0.086, 0.015)	0.1693
		Fluticasone	0.006 (−0.043, 0.055)	0.8140

		Montelukast	−0.022 (−0.070, 0.026)	0.3753
$FEF_{25–75}$	0–12 weeks	Combination	0.686 (0.461, 0.910)	<0.0001
		Fluticasone	0.902 (0.671, 1.134)	<0.0001
		Montelukast	−0.245 (−0.477, −0.012)	0.0393
	12–48 weeks	Combination	−0.107 (−0.235, 0.022)	0.1044
		Fluticasone	0.042 (−0.087, 0.171)	0.5238
		Montelukast	0.040 (−0.090, 0.169)	0.5483
XA	0–12 weeks	Combination	−0.893 (−1.544, −0.242)	0.0073
		Fluticasone	−0.256 (−0.889, 0.378)	0.4293
		Montelukast	−0.047 (−0.697, 0.603)	0.8876
	12–48 weeks	Combination	−0.116 (−0.484, 0.253)	0.5394
		Fluticasone	−0.656 (−1.008, −0.303)	0.0003
		Montelukast	−0.088 (−0.451, 0.274)	0.6325

Table 2: Differences in slopes for tests of lung function in the first 12 weeks and from 12 to 48 weeks of treatment

Lung Function	Time	Treatment	Estimate (95% CI)	Probability
FEV_1	0–12 weeks	C vs. F	−0.275 (−0.443, −0.107)	0.0014
		C vs. M	0.331 (0.164, 0.499)	0.0001
		F vs. M	0.606 (0.439, 0.774)	<.0001
	12–48 weeks	C vs. F	0.011 (−0.084, 0.105)	0.8247
		C vs. M	0.000 (−0.094, 0.094)	0.9988
		F vs. M	−0.011 (−0.104, 0.083)	0.8237
FEV_1 /FVC	0–12 weeks	C vs. F	−0.150 (−0.276, −0.024) F vs. M	0.0199
		C vs. M	0.210 (0.086, 0.335)	0.0010
		F vs. M	0.360 (0.237, 0.483)	<.0001
	12–48 weeks	C vs. F	−0.041 (−0.112, 0.029)	0.2489
		C vs. M	−0.014 (−0.084, 0.056)	0.7008
		F vs. M	0.028 (−0.041, 0.096)	0.4292
$FEF_{25–75}$	0–12 weeks	C vs. F	−0.217 (−0.539, 0.106)	0.1887
		C vs. M	0.930 (0.607, 1.254)	<.0001
		F vs. M	1.147 (0.819, 1.475)	<.0001
		C vs. F	−0.149 (−0.331,	0.1099

	12–48 weeks		0.033)	
		C vs. M	−0.146 (−0.329, 0.036)	0.1162
		F vs. M	0.002 (−0.180, 0.185)	0.9803
XA	0–12 weeks	C vs. F	−0.637 (−1.546, 0.271)	0.1694
		C vs. M	−0.846 (−1.766, 0.074)	0.0717
		F vs. M	−0.209 (−1.116, 0.699)	0.6522
	12–48 weeks	C vs. F	0.540 (0.030, 1.050)	0.0382
		C vs. M	−0.027 (−0.544, 0.490)	0.9184
		F vs. M	−0.567 (−1.073, −0.062)	0.0281
Abbreviations: C = Combination; F = Fluticasone; M = Montelukast				