Original Article

Role of impulse oscillometry in diagnosis and follow-up in bronchial asthma

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ABSTRACT

Background: Asthma is defined as a chronic inflammatory disorder of the airways, characterized by bronchial hyper-responsiveness and variable airflow obstruction, that is often reversible either spontaneously or with treatment. Impulse oscillometry is a newer diagnostic modality for asthma. It is based on the measurement of sound waves reflected by airway resistance. **Objectives:** The aim of this article is to study the role of impulse oscillometry in diagnosis and follow-up of bronchial asthma. **Methods:** Fifty-five clinically diagnosed bronchial asthma patients were evaluated with spirometry and impulse oscillometry before and after 3 months of inhaled treatment. The sensitivity to diagnose and follow-up was compared using proper statistical tests. **Results:** Impulse oscillometry was superior to spirometry in diagnosing bronchial asthma and also in accessing the treatment response after 3 months. **Conclusion:** Impulse oscillometry is superior in predicting bronchial asthma and its parameters are also more sensitive in accessing treatment response. It can replace spirometry as it is easy to perform and effort independent.

KEY WORDS: Bronchial asthma, impulse oscillometry, spirometry

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Submitted: 12-May-2022 **Revised:** 21-Aug-2022 **Accepted:** 23-Oct-2022 **Published:** 29-Dec-2022

INTRODUCTION

Asthma is defined as a chronic inflammatory disorder of the airways which manifests itself as recurrent episodes of wheezing, breathlessness, chest tightness and cough. It is characterized by bronchial hyper-responsiveness and variable airflow obstruction that is often reversible either spontaneously or with treatment. The prevalence of asthma in India is about 2%, and asthma is responsible for significant morbidity. In India, the estimated cost of asthma treatment per year for the year 2015 has been calculated at about 139.45 billion.[1]

Access this article online

Quick Response Code:

Website: www.lungindia.com

DOI: 10.4103/lungindia.lungindia_251_22

It is considered as a major public health problem in most countries, regardless of their level of development. Patients with asthma need to be monitored regularly. There are many methods including subjective and objective measures. Subjective measures usually consist of a series of questions based on clinical assessment and quality-of-life questionnaires. Spirometry, peak flow measurement and bronchoprovocation testing constitute the traditional objective means of measuring asthma.[2]

How to cite this article: Mandilwar S, Thorve SM, Gupta V, Prabhudesai P. Role of Impulse Oscillometry in diagnosis and follow-up in bronchial asthma. Lung India 2023;40:24-32.

The management of asthma requires sufficient adherence to preventive and therapeutic interventions to achieve adequate control of disease. Control of asthma can be defined as minimal or no symptoms, optimal pulmonary function test, few or no exacerbations and the ability to enjoy normal activities.

There is overlap in bronchodilator reversibility and other measures of variation between health and disease. In a patient with respiratory symptoms, the greater the variations in their lung function or the more times excess variation is seen, the more likely the diagnosis is to be asthma. If forced expiratory volume in 1 s (FEV1) is within the predicted normal range when the patient is experiencing symptoms, this reduces the probability that the symptoms are due to asthma.[3]

Impulse oscillometry (IOS) is a newer diagnostic modality. It is based on measurement of sound waves reflected by airway resistance. It is an advanced spirometry technique, patient friendly and does not require any tedious and exhaustive breathing manoeuvres. The important aspect regarding the IOS is that it has much higher sensitivity than FEV1 and peak expiratory flow. It is done during normal tidal breathing, so it requires much less patient effort and cooperation. It can also be used when spirometry is not possible in paediatric population.[4]

The basis of oscillometry is to use external forcing signals of sound waves applied either continuously or in a time-discrete manner.[5] IOS machine produces and transmits small pressure pulses down the trachea-bronchial tree and records pressure and flow changes at the mouth.

The role of IOS in bronchial asthma is much more studied and is found relatively more informative as compared to chronic obstructive pulmonary disease (COPD). IOS is a useful diagnostic tool in early asthma development and might be a helpful objective outcome measure of early interventions.[4] There are several studies regarding the role of IOS in asthma and in asthmatic children outside India. Very few studies have been done in India on IOS.

Aims and objectives

1. To evaluate the role of IOS in cases of bronchial asthma.
2. To study the clinical response of treatment with respect to IOS and spirometry in asthmatic patients.

METHODOLOGY

The study is a prospective study carried out on patients attending pulmonary medicine out patient department (OPD) of Lilavati Hospital and Research Centre who were diagnosed as bronchial asthma (not on regular medications and taking inhalers only as per requirement), and those who satisfy the inclusion and exclusion criteria were included in study after written informed consent.

Inclusion criteria

1. Patients who had been clinically diagnosed as bronchial asthma.
2. Patients of age group more than 13 years and of both sexes.
3. Asthma patients who could perform spirometry.
4. Patients willing to follow up after 3 months.

Exclusion criteria

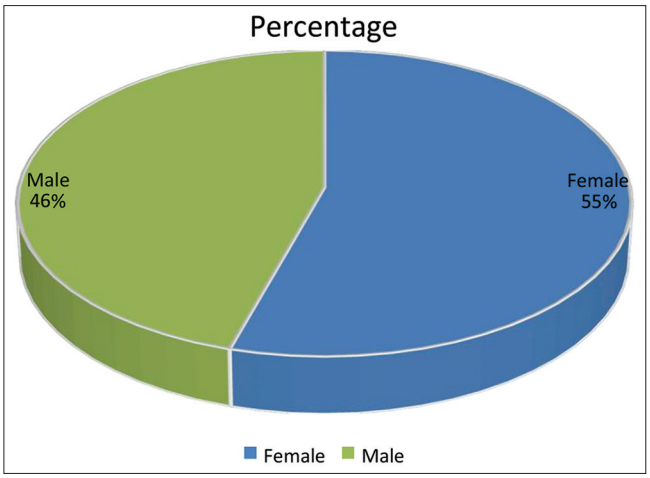
1. Patients who were not able to perform IOS and/or spirometry correctly.
2. Patients with co-morbidities like ischemic heart disease, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, interstitial lung disease, renal failure and history of smoking.
3. Patients who did not consent.
4. Pregnant females.

Patients were interviewed in detail and were clinically examined. Age, sex, height, weight and body mass index (BMI) were noted. Patients were interviewed in detail regarding clinical symptoms, history of asthma/atopy and family history, exacerbation, seasonal and diurnal variations and any aggravating allergic factors.

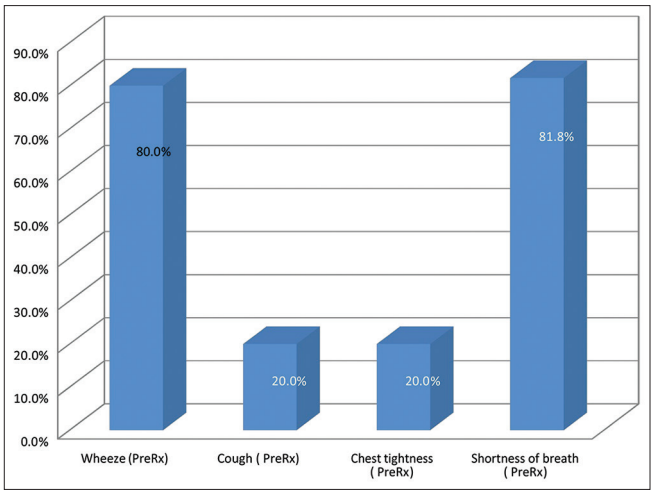
Fifty five such patients with a history of asthma or unexplained shortness of breath were evaluated at the baseline with spirometry and IOS. The diagnosis of asthma was made by history of wheezing, cough, chest tightness and shortness of breath. Patients with smoking history were excluded. Patients with history of second-hand smoke were also excluded. The patients were routinely given inhaled bronchodilators and the same measurements were obtained following its administration. Patients were then followed up at a minimum of 3 months of treatment with various inhaled bronchodilators.

Spirometry and IOS diagnostics were conducted utilizing a Jaeger (c) instrument. The technique of IOS measurement was as described in. Briefly, patients were seated comfortably in a non-swivel chair. Nose clips were applied, and a special mouthpiece was used. Patients were allowed to breathe normally while a loudspeaker component of the instrument delivered intermittent multi-frequency impulses over a minimum of 30 s duration. A trained technician guided, comforted and assisted the patient in following the tracing and at least three sinusoidal readings were obtained. We chose the recording with the best coherence at frequencies from 5 to 30 Hz. The ideal coherence was 0.9, 1, 1, and 1 at 5, 10, 15 and 20 Hz, respectively. The values we obtained were recorded as R5, R20 and X (the impedance reactance at R5 and above). We then recorded spirometry after IOS in the same sitting. FEV1 was recorded, and the results were obtained according to the guidelines of the American Thoracic Society.

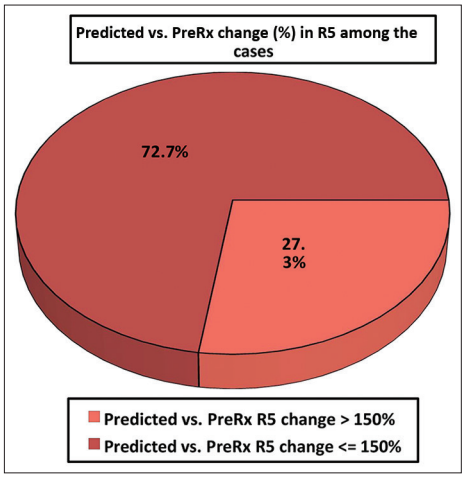
Patients were treated with various inhaled corticosteroids (ICS) or ICS/LABA (inhaled corticosteroid and long-acting beta-agonist combination). We noted post-treatment results at least 3 months later.



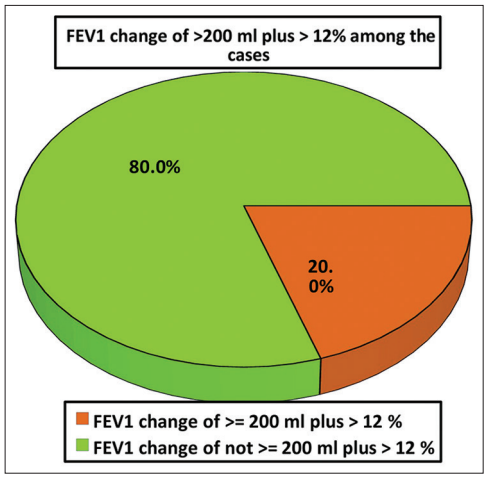
Graph 1: Gender distribution of cases



Graph 2: Symptoms at time of presentation



Graph 3: Patient diagnosed as bronchial asthma on the basis of IOS using IOS criteria (R5 more than 150%)



Graph 4: Patient diagnosed as a case of bronchial asthma using spirometry reversibility criteria (FEV1 change of more than 200 ml and more than 12%)

Comparison between IOS and spirometry findings with clinical symptoms was done. Data of all patients included collected in the data collection proforma attached herewith. Appropriate statistical methods applied to analyse the data. The co-relation of IOS with the disease severity and their impact and outcome was analysed.

Out of 55 cases, 30 patients (54.5%) were females and 25 patients (45.5%) were males [Graph 1 and Table 1].

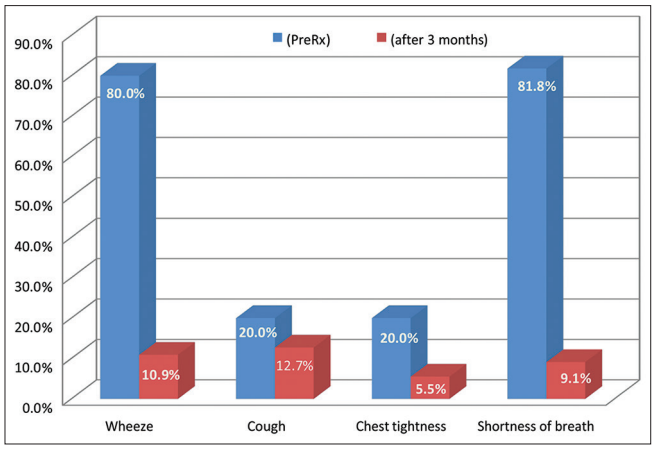
Out of 55 patients, 45 (81.8%) patients were having shortness of breath at the time of presentation, whereas 44 (80%) patients were having wheeze, 11 (20%) had cough and 11 (20%) had chest tightness [Graph 2 and Table 2].

Total number of patients diagnosed with spirometry and IOS together were 15. All patients who were diagnosed with asthma by spirometry also showed supportive data by oscillometry test. Four patients in whom spirometry was not fulfilling reversibility criteria were positive by oscillometry test [Table 3].

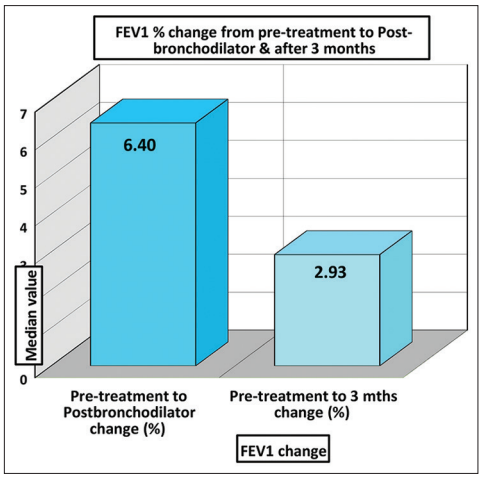
Patients diagnosed as a case of bronchial asthma at the time of presentation using IOS criteria were 15 (27.3%), whereas 40 patients (72.7%) were having normal IOS values [Graph 3 and Table 4]. Patients diagnosed as a case of bronchial asthma at the time of presentation using spirometry reversibility criteria were 11 and 44 patients were having normal spirometry values [Graph 4 and Table 5].

After 3 months of bronchodilator therapy, all the symptoms decreased. Shortness of breath decreased from 81% of patients to 9.1% of patients, similarly wheeze from 80.0% to 10.9% and cough 20% to 12.7% and chest tightness from 20% to 5.5% [Graph 5 and Table 6].

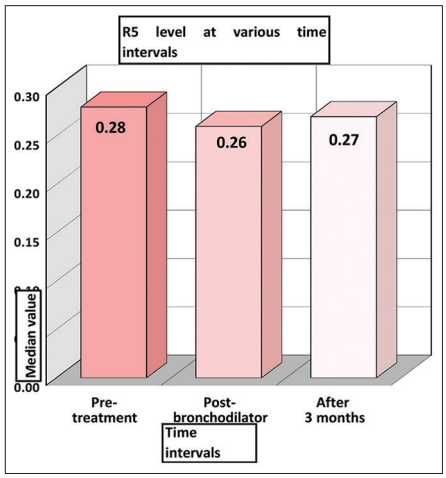
The pre-treatment median R5 in our study was 0.28 and post-bronchodilator was 0.26, after giving bronchodilator treatment for 3 months the median R5 was 0.27 [Graph 7].



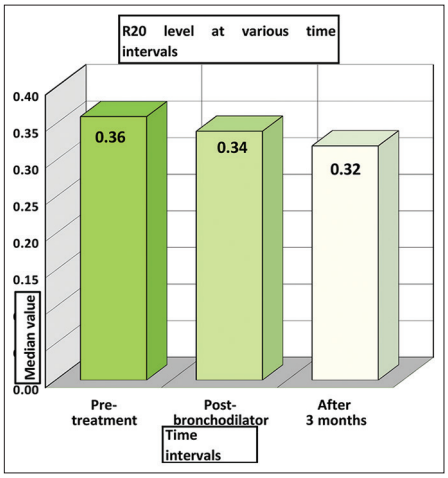
Graph 5: Symptoms after 3 months of bronchodilator therapy as compared with initial symptoms



Graph 6: FEV1% change from pre-treatment to post-bronchodilator and after 3 months



Graph 7: Change in R5 post-bronchodilator and after 3 months



Graph 8: Change in R20 post-bronchodilator and after 3 months

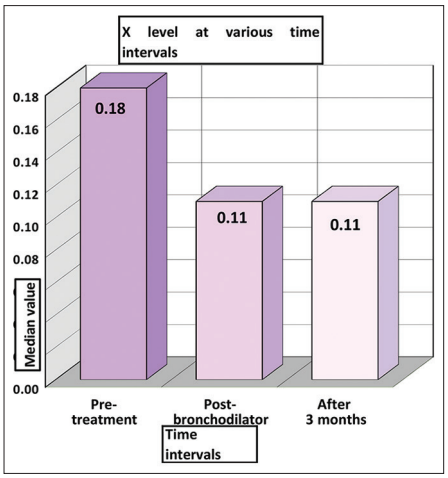
The comparison between median values of R5 pre-treatment to post-bronchodilator was of statistical significance. The comparison between median values of R5 pre-treatment to 3 months of bronchodilator therapy was of statistical significance [Table 8]. The pre-treatment median R20 in our study was 0.36 and post-bronchodilator was 0.34, after giving bronchodilator treatment for 3 months the median R5 was 0.32 [Graph 8]. The comparison between median values of R20 pre-treatment to post-bronchodilator was of statistical significance. The comparison between median values of R20 pre-treatment to 3 months of bronchodilator therapy was of statistical significance [Table 9]. The pre-treatment median X in our study was 0.18 and post-bronchodilator was 0.11; after giving bronchodilator treatment for 3 months, the median R5 was 0.11 [Graph 9]. The comparison between median values of X pre-treatment to post-bronchodilator was of statistical significance [Table 10]. The comparison between median values of X pre-treatment to 3 months of bronchodilator therapy was of statistical significance. The pre-treatment median FEV1 in our study was 1.71 and post-bronchodilator was 1.90, after giving bronchodilator treatment for 3 months the median FEV1 was 1.80 [Graph 10]. The comparison between median values of FEV1 pre-treatment to post-bronchodilator was of statistical significance. The comparison between median values of FEV1 pre-treatment to 3 months of bronchodilator therapy was of statistical significance [Tables 7 and 11].

Pre-treatment pre-bronchodilator R5 compared to the FEV1, the co-relation was −0.0128 (minus sign indicates FEV1 increases but resistance decreases).

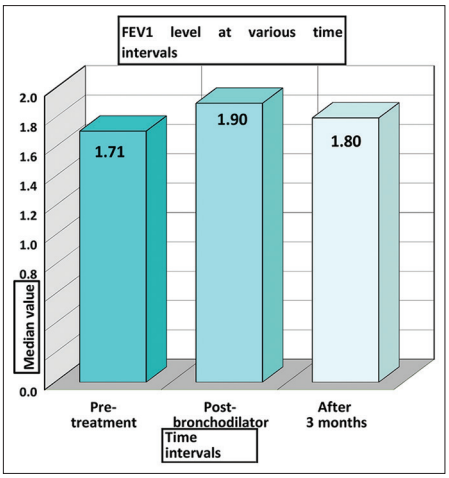
Pre-treatment post-bronchodilator R5 compared to the FEV1, the co-relation was −0.075.

Post-treatment FEV1 (after 3 months) was compared with post-treatment R5 (after 3 months), it was seen that correlation was −0.087 [Table 12].

After selecting patients for study, change in R5 was compared to change in FEV1 after administration of short-acting bronchodilator; it was seen that change in



Graph 9: Change in reactance X post-bronchodilator and after 3 months



Graph 10: Change in FEV1 post-bronchodilator and after 3 months

Table 1: Gender distribution of cases

Sex	No.	Percentage (%)
Female	30	54.5
Male	25	45.5
Total	55	100.0

Table 2: Symptoms after 3 months of bronchodilator therapy as compared with initial symptoms

Symptom	No.	Percentage (%)
Wheeze (PreRx)	44	80.0
Cough (PreRx)	11	20.0
Chest tightness (PreRx)	11	20.0
Shortness of breath (PreRx)	45	81.8

R5 post-bronchodilator, compared to change in FEV1, was statistically significant (*P*-value is −0.029).

Similarly after giving 3 months of bronchodilator therapy, change in R5 was compared to change in FEV1. It was observed that change in R5 post-bronchodilator treatment after 3 months compared to change in FEV1 post-bronchodilator treatment for 3 months was statistically significant (*P*-value −0.062) [Table 13].

DISCUSSION

This study included 55 patients studied over a period of 20 months. In our study, 25 (45.5) were males and 30 (55.5%) were females. Study showed increased prevalence of disease among female study by Jindal.[6] and Chhabra[7] *et al*. found higher incidence of asthma in females in India. The mean age in our study is 48.76 years, minimum age is 19 and maximum is 84 years. The median BMI in our study is 24.67, minimum BMI is 16.36 and maximum BMI is 44.38. Obesity (BMI more than 30 kg/m^2) is associated with poorer asthma control as shown by Taylo *et al*.[8]

In our study, budesonide and formoterol combination was used by 41 (74.5%) patients, fluticasone and salmetrol by 11 (20%), and ciclosonide by 3 (5.5%) patients. IOS served as one of the multiple outcome measures for the effectiveness of inhaled budesonide in 2–5-year-old children.[9] In symptomatic adolescent and adult patients with asthma maintenance and reliever therapy with a single-inhaler fixed combination of dry powder budesonide + formoterol, fumarate dihydrate is an evidenced option.

The combination treatment is convenient to patients. It reduces the number of exacerbations requiring treatment with oral corticosteroids. In some patients, the strategy may also reduce the total intake of inhaled corticosteroids over time. Whether important outcome measures of asthma treatment, such as hospital admission and emergency room visit rates, may be reduced is less well documented since the published studies may have been influenced by publication bias. Non-pharmaceutical company-sponsored research evaluating such measures is needed. There is no evidence for the use of single inhaler fixed combinations of inhaled corticosteroids + long-acting β2-agonists in children (<12 years of age), and budesonide + formoterol fumarate dihydrate should not be prescribed to the age group.[10]

Salmetrol and fluticasone combination also significantly improved other efficacy outcomes including asthma symptom score, frequency of short-acting beta-agonist treatment, frequency of unscheduled visits to clinic and frequency of exacerbation due to virus infection.[11] Formoterol and ciclosonide provide better improvement than ciclosonide alone in terms of lung function and symptoms without increased risk of adverse events in asthma patients.[11]

Association among the cases between FEV1 change of more than 200 ml plus more than 12% and R5 change more than 150% was of statistical significance (*P* value of Fisher's exact test is 1.14E−08). Total number of patients diagnosed with spirometry and IOS cumulatively were 15. All patients who were diagnosed with asthma by

Table 3: Association of spirometry parameters (i.e. FEV1 change of >200 ml plus >12%) and impulse oscillometry parameter (i.e. R5 change >150%) for diagnosis of bronchial asthma

FEV1 change of >200 ml plus>12%		R5-predicted vs. PreRx change >150%		Total
		Yes	No	
Yes	No	11	0	11
	%	100.0	0.0	100.0
No	No	4	40	44
	%	9.1	90.9	100.0
Total	No	15	40	55
	%	27.3	72.7	100.0

Chi-square tests	Value	df	*P*	Association is
Pearson Chi-square[$]	36.667 (b)	1	1.40E09	Significant
Continuity correction[$]	32.227	1	1.37E08	Significant
Fisher's exact test			1.14E08	Significant

[$]One cell (25.0%) has expected count less than 5. *P* value of Fisher's exact test will be used

Symmetric measures	Statistical test used	Value	Approx. T	*P*	Agreement is
Measure of agreement	Kappa	0.8	6.055	1.40E−09	Significant

Table 4: Patient diagnosed as bronchial asthma using Impulse Oscillometry (R5 change of more than 150%)

R5-predicted vs. PreRx change >150%	No.	Percentage (%)
Yes	15	27.3
No	40	72.7
Total	55	100.0

Table 5: Patient diagnosed as bronchial asthma using Spirometry (FEV1 change of more than 200ml and 12%)

FEV1 change of >200 ml plus >12%	No.	Percentage (%)
Yes	11	20.0
No	44	80.0
Total	55	100.0

Table 6: Symptoms at time of diagnosis and after 3 months of bronchodilator treatment

Symptom	PreRx	After 3 months
Wheeze	80.0%	10.9%
Cough	20.0%	12.7%
Chest tightness	20.0%	5.5%
Shortness of breath	81.8%	9.1%

spirometry also showed supportive data by oscillometry test. Four patients in whom spirometry was not fulfilling reversibility criteria were positive by oscillometry test.

IOS measures both small and large airways resistance and resonance capacitance of the lung. Its main advantage is its ability to perform these measurements in a non-invasive, relatively effort independent and minimally intrusive manner during spontaneous normal tidal breathing.[12]

In contrast to traditional spirometry, IOS traces its findings independent of age, height, weight or gender on adolescents and adults aged 13 years or older. The most relevant outcome of IOS measures includes R5 (resistance in small airways), R15 or higher (resistance in larger airways) and AX (low frequency integrated impedance reactance at R5).[12]

IOS is diagnostic manoeuvre which is a non-invasive and effort-independent technique where the respiratory resistance is obtained by the forced oscillation (Rfo). It is an add-on tool to spirometry in the diagnosis of obstructive airway diseases.

The actual values of respiratory resistance at 5 and 20 Hz (R5 and R20, respectively) and distal capacitive reactance at 5 Hz (X5) were recorded.

Proximal obstruction: Total respiratory resistance R5 is higher than 150% predicted R5 and within abnormal range. The resistance spectrum R (*f*) is independent of frequency and almost horizontal, that is proximal respiratory resistance R20 is similar to total respiratory resistance R5. Distal capacitive reactance X5 is completely within the normal range, as the resonant frequency.

Peripheral obstruction

1. The R5 is within abnormal range, that is >150% predicted, and the R20 is considerably lower than R5.
2. The R (*f*) is frequency dependent becoming less at higher frequencies.

The X5 is reduced into the abnormal range, and the f_{res} is shifted to the right (to the higher frequencies).

The resistive component of respiratory impedance, R_{rs}, includes proximal and distal airways (central and peripheral), lung tissue and chest wall resistance. Normally, central resistance dominates, depending on airway calibre and the surface of the airway walls, while lung tissue and chest wall resistance are usually negligible. R_{rs} may be considered within normal limits if R_{rsat} 5 Hz (Rrs5) is within 1.64 SD of the predicted value. Rrs5 values between 1.64 and 2 SD above predicted may be considered minor, more than 2 SD moderate and more than 4 SD above predicted severe obstruction.

Proximal airways obstruction elevates R_{rs} evenly independent of oscillation frequency.[13] In distal airways'

Table 7: Comparison of change in FEV1 (%) from pre-treatment, post-bronchodilator after 3 months

Variables	No.	Mean	SD	Median	IQR	*t*	*P*	Difference is
FEV1-PriorRx to Post-bronchodilator change (%)	55	5.22	9.15	6.40	10.5 4	2.936	0.004 9	Significant
FEV1-PriorRx to 3 months change (%)	55	4.67	13.16	2.93	12.00	1.73	0.0894	Not significant

Table 8: Comparison of values of R5 at pre-treatment, post-bronchodilator and after 3 months

Variables^	No.	Mean	SD	Median	IQR	Chi-square	*P*
PriorRx-R5	55	0.38	0.30	0.28	0.33	24.111	0.0000058
R5 (post-bronchodilator)	55	0.36	0.31	0.26	0.29	Difference is significant	
R5 after 3 months	55	0.35	0.27	0.27	0.29		

^Data failed 'Normality test'. Hence, Friedman repeated measures analysis of variance on ranks applied

Table 9: Comparison of values R20 at pre-treatment, post-bronchodilator and after 3 months

Variables^	No.	Mean	SD	Media *n*	IQR	Chi-square	*P*
PriorRx-R20	55	0.37	0.13	0.36	0.17	24.873	0.00000397
R20 (post-bronchodilator)	55	0.36	0.16	0.34	0.17	Difference is significant	
R20 after 3 months	55	0.34	0.13	0.32	0.20		

^Data failed 'Normality test'. Hence, Friedman repeated measures analysis of variance on ranks applied

Table 10: Comparison of values of reactance X at pre-treatment, post-bronchodilator and after 3 months

Variables^	No.	Mean	SD	Median	IQR	Chi-square	*P*
PriorRx-X	55	0.15	0.22	0.18	0.30	7.891	0.01934
X (post-bronchodilator)	55	0.11	0.17	0.11	0.22	Difference is significant	
X after 3 months	55	0.12	0.19	0.11	0.27		

^Data failed 'Normality test'. Hence, Friedman repeated measures analysis of variance on ranks applied

Table 11: Comparison of values of FEV1 at pre-treatment, post-bronchodilator and after 3 months

Variables^	No.	Mean	SD	Median	IQR	Chi-square	*P*
PreRx-FEV1	55	1.97	0.90	1.71	1.46	13.486	0.0012
FEV1 (post-bronchodilator)	55	2.05	0.90	1.90	1.37	Difference is significant	
FEV1 (after 3 months)	55	2.04	0.92	1.80	1.25		

^Data failed 'normality test'. Hence, Friedman repeated measures analysis of variance on ranks applied

Table 12: Statistical correlation between FEV1 and R5 at various intervals among the cases

Variables	PreRx-ae no. bFEV1	PreRx-R5	FEV1 (post-bronchodilator)	R5 (post-bronchodilator)	FEV1 (after 3 months)	R5 after 3 months
PreRx-FEV1						
Pearson correlation	1	−0.128	0.974**	−0.131	0.970**	−0.102
P		0.3528	1.12E−35	0.3422	3.81E34	0.4568
PreRx-R5						
Pearson correlation	−0.128	1	−0.066	0.974**	−0.111	0.981**
P	0.3528		0.6345	6.61E36	0.4188	2.91E−39
FEV1 (post-bronchodilator)						
Pearson correlation	0.974**	−0.066	1	−0.075	0.979**	−0.041
P	1.12E−35	0.6345		0.5862	3.77E38	0.7675
R5 (post-bronchodilator)						
Pearson correlation	−0.131	0.974**	−0.075	1	−0.112	0.977**
P	0.3422	6.61E−36	0.5862		0.4147	3.26E−37
FEV1 (after 3 months)						
Pearson correlation	0.970**	−0.111	0.979**	−0.112	1	−0.087
P	3.81E−34	0.4188	3.77E−38	0.4147		0.5253
R5 after 3 months						
Pearson correlation	−0.102	0.981**	−0.041	0.977**	−0.087	1
P	0.4568	2.91E−39	0.7675	3.26E37	0.5253	

**Correlation is significant at the 0.01 level (2-tailed)

obstruction, R_{rs} is highest at low oscillation frequencies and falls with increasing frequency. This negative frequency-dependence of R_{rs} has been explained in terms of intrapulmonary gas flow redistribution, due either to peripheral pulmonary non-homogeneities or to changes in peripheral elastic reactive properties.[13]

Table 13: Statistical correlation between FEV1 and R5% change between various intervals among the cases

Variables	FEV1 PreRx to Post-bronchodilator change (%)	R5PreRx post-bronchodilator change (%)	FEV1-PreRx to 3 months change (%)	R5-PreRx to 3 months change (%)
FEV1-PreRx to				
Pearson	1	−0.029	0.452 (**)	−0.165
Post-bronchodilator change (%)				
Correlation				
P		0.8353	0.0005	0.2298
R5-PreRx post-bronchodilator change (%)				
Pearson correlation	−0.029	1	0.057	0.564**
P	0.8353		0.6811	7.46E−06
FEV1-PreRx to 3 months change (%)				
Pearson correlation	0.452**	0.057	1	−0.062
P	0.0005	0.6811		0.6515
R5-PreRx to 3 months change (%)				
Pearson correlation	−0.165	0.564**	−0.062	1
P	0.2298	7.46E−06	0.6515	

**Correlation is significant at the 0.01 level (2-tailed)

As peripheral resistance increases, R_{rs} becomes more frequency dependent. Frequency dependence of R_{rs} may be a normal finding in small children and may be greater than in adults in the presence of peripheral airflow obstruction.[13]

The pulmonary function test most commonly used to detect small airway impairment and asthma is spirometry, which measures the volume of air that can be moved in or out of the lungs as a function of time with rapid and maximal inspiratory and expiratory efforts. This requires a considerable degree of cooperation from the subject, which is difficult to achieve for older children and cannot be achieved by younger children. This makes the diagnosis of small airway impairment and asthma difficult owing to the lack of objective measurements for younger children.[14,15] Furthermore, it has been reported that some asthmatic patients do not improve spirometrically, despite clinical improvement with treatment. This is of concern, because if asthma is not appropriately controlled, it can lead to permanent airway damage.[16]

IOS is used to diagnose, evaluate disease severity, and assess therapeutic responses in chronic lung diseases such as asthma and cystic fibrosis. IOS may help distinguish between asthma, chronic bronchitis and emphysema based on differences in pulmonary resistance, frequency dependence of resistance and pulmonary reactance.[16] It also has been used to determine lung function in individuals with stable asthma and during provocation by methacholine.[17] In the emergency room setting, IOS may be used to evaluate lung function and assess response to treatment of acutely ill children with asthma, who may be unable to perform forced expiratory manoeuvres.[18] Relative to this use, correlations have been shown between FEV1 and forced vital capacity by spirometry and impedance and resistance by IOS in children with hyperactive airways.[19] Of practical interest, an established Current Procedural Terminology reimbursement code exists for IOS testing that is completely separate from the code for spirometry.

IOS also may be applied in epidemiological settings to screen for asthmatic children[20] and to examine bronchial responsiveness to methacholine challenge test in active working adults exposed to occupational respiratory irritants and cigarette smoke. The ability to transport the IOS apparatus and measure effort-independent lung function *n* parameters highlights the utility of IOS to assess respiratory dysfunction at the bedside in critically ill patients[21] and determine optimal parameters for mechanical ventilation from the patient's pulmonary resistance and elastance.[22] In obstructive sleep apnoea syndrome, IOS has been used to evaluate the degree of upper airway obstruction,[23] determine the optimal continuous positive airway pressure required to treat the obstruction[24] and estimate the resolution of obstruction subsequent to surgical intervention.

Limitations

In our study, patients represent a heterogeneous group since they were placed on different types of inhaled bronchodilators.

CONCLUSION

1. IOS is better in identifying bronchial asthma cases as compared to spirometry.
2. R5-pre-treatment to R5-3 months' change is statistically significant and better predictor of improvement at the end of 3 months as compared to FEV1 change which is not significant after 3 months of therapy. IOS is better predictor of long-term inhaled bronchodilator therapy as compared to spirometry in patients of bronchial asthma.
3. IOS is almost independent of patient cooperation. Assessment and differentiation of airway function are done under quiet breathing conditions. It can test a larger patient range than spirometry alone, from children, adult to geriatric patients.
4. IOS measures impedance at different frequencies indicative of central and peripheral airway resistance. It allows differentiation of central (proximal) airways' resistance and peripheral (distal) airways' resistance.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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