

# Impulse oscillometry to differentiate between chronic obstructive pulmonary disease and bronchial asthma

Mona M. Ahmed, Maryam A.A. Kader, Esraa M. Mohammed

**Background** The impulse oscillation system (IOS) yields useful clinical data that predominantly include functional assessment of peripheral airways more than that available from commonly used spirometry. The aim of this study was to differentiate between chronic obstructive pulmonary disease (COPD) and bronchial asthma using IOS.

**Patients and methods** This study was carried out on 40 patients; 20 patients were diagnosed with bronchial asthma and the remaining 20 patients had a clinical diagnosis of COPD. All patients underwent baseline IOS and spirometry, and then after 15 min of inhalation of 400 µg salbutamol, spirometry was repeated in all patients.

**Results** A highly statistically significant difference was found between asthma patients and COPD patients in R20, whereas no statistically significant difference was found between the two studied groups in R5, X5. There was a statistically significant difference between asthma patients and COPD patients in resistance; 75% of asthmatic patients had increased total airway resistance, mainly proximal, 20% had increased total airway resistance, mainly peripheral, and 5% had normal airway resistance, whereas all COPD patients had increased total airway resistance, mainly peripheral. No significant correlation was found between IOS parameters and spirometric parameters in COPD or asthmatic patients, but in both groups, there was a significant correlation between forced expiratory volume 1 (FEV<sub>1</sub>) and R5, X5.

## Introduction

Chronic obstructive pulmonary disease (COPD) is a common preventable and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is because of airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases [1].

Asthma is a heterogeneous disease, usually characterized by chronic airway inflammation. It is defined by a history of respiratory symptoms such as wheeze, shortness of breath, chest tightness, and cough that vary over time and in intensity, together with variable expiratory airflow limitation [2].

The impulse oscillation system (IOS) can access airway resistance and reactance at different oscillatory frequencies to detect properties not assessable by spirometry [3].

## Patients and methods

The present study included 40 patients admitted either at the Pulmonology Department of Ain Shams University

**Conclusion** IOS provides useful clinical information that prominently includes functional assessment of small, peripheral airway behavior beyond that available from commonly used pulmonary function tests. IOS also aids differentiation between COPD and bronchial asthma. COPD patients had increased airway resistance, mainly in the peripheral airways, whereas asthmatic patients had increased airway resistance, mainly in the proximal airways. R20 is the best IOS parameter to differentiate between these two diseases.

*Egypt J Bronchol* 2018 12:373–378

© 2018 Egyptian Journal of Bronchology

*Egyptian Journal of Bronchology* 2018 12:373–378

**Keywords:** asthma, chronic obstructive pulmonary disease, impulse oscillometry, reactance, resistance

Department of Pulmonary Medicine and Tuberculosis, Faculty of Medicine, Ain Shams University, Cairo, Egypt

Correspondence to Esraa Mohammed Mohammed, Master of Chest Diseases, Resident of Pulmonary Medicine and Tuberculosis, Faculty of Medicine, Ain Shams University, Cairo, Egypt. Tel: 01003179212; e-mail: rokahamza6@gmail.com

**Received** 8 September 2017 **Accepted** 15 December 2017

Hospital or visiting the chest clinic during the period between January 2017 and June 2017.

Patients were divided into two groups as follows:

Group A included 20 stable COPD patients according to GOLD criteria.

Group B included 20 stable bronchial asthma patients according to GINA criteria.

## Patients with bronchial asthma

Both groups A and B stopped short-acting bronchodilator inhalers 6 h before spirometry, long-acting bronchodilator 12 h before the test, and sustained-release theophylline 24 h before the test.

All patients subjected to the following: assessment of full medical history, full clinical assessment, spirometry

---

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

(before and after administration of bronchodilators), and impulse oscillometry test, which was performed once, to measure airway resistance and reactance.

#### *The following patients were excluded*

Patients with exacerbation in the last 3 months, patients with other obvious respiratory diseases, and patients with comorbidities such as diabetes and ischemic heart diseases.

A Jaeger MasterScreen Impulse Oscillometry system (Jaeger Co, Wurzburg, Germany) with a built-in program was used to perform spirometry and impulse oscillometry [4].

#### *Both procedures were performed as follows:*

The tests were explained to the patients. The patient was asked about activities that had to be avoided before the tests. Weight and height were measured and recorded.

#### *Spirometry procedure*

The 'spirometry' test was started after choosing its icon from the main group. Patient sit and elevate his head in front of the device. Then, the patient inhaled completely and rapidly with a pause of less than 1 s at total lung capacity. Patient closed his mouth around the mouth piece. Then, the patient exhaled maximally in an upright position. The patient had to repeat these steps a minimum three times [5].

IOS procedure: according to the MasterScreen Instruction Manual [4].

The 'IOS' test was started after choosing its icon from the main group. The test was started after a click was heard. A nose clip was used to close the patient's nose was closed by anose clip and then the patient approaches the mouthpiece of the device. To prevent measuring impulses produced in the loud speaker generator from being lost through the cheeks, the patient sat upright and maintained his/her head straight or slightly extended. Also, to avoid artifacts in the mouth, the patient had to press his/her hands tightly against his/her cheeks; the patient was asked to put the mouthpiece between his/her teeth and keep his/her mouth firmly sealed around the mouthpiece. The patient breathed in and out regularly. After a minimum of four breaths or normally after a defined period of time (30 s) has passed, the measurements can be ended manually; otherwise, it stops automatically after a maximum period of 90 s.

#### **Diagnosis of airway obstruction by spirometry and impulse oscillation system**

##### *Spirometry*

The obstructive pattern is identified by:

- (1) Forced expiratory volume 1 ( $FEV_1$ ) below 80% predicted.
- (2) Forced vital capacity (FVC) can be normal or reduced (usually to a lesser degree than  $FEV_1$ ).
- (3)  $FEV_1/FVC$  ratio below 70% [1].

#### **Impulse oscillometry**

##### *Proximal obstruction*

- (1) Total airway resistance R5 is considered abnormal when it is more than 150%
- (2) The resistance spectrum  $R(f)$  is horizontal and not related to frequency, that is, proximal airway resistance R20 is almost equal to total respiratory resistance R5.
- (3) Normal reactance is found in proximal obstruction, as the resonant frequency [6].

##### **Peripheral obstruction**

- (1) The R5 is more than 150%, that is, beyond the normal range; also, the R20 value is less than that of the R5 value.
- (2) The  $R(f)$  is frequency dependent, becoming lower at higher frequencies.
- (3) Airway reactance X5 is reduced, and there is a right shift of the fres toward higher frequencies.

#### **Statistical analysis**

- (1) Descriptive statistics: to describe normally distributed quantitative data, we used mean and SD.
- (2) Analytical statistics: to compare quantitative variables, we used an unpaired  $t$ -test; also, qualitative variables were compared using the  $\chi^2$ -test.

#### **Results**

The COPD group included 20 patients; 18 were men, whereas the remaining two were women, mean age  $58.20 \pm 6.64$ , mean weight  $70.00 \pm 15.96$ , and mean height  $163.45 \pm 8.13$ . Nineteen of these patients were smokers, whereas one patient was a nonsmoker.

The bronchial asthma group included 20 patients; 14 were women, whereas the remaining six were men, mean age  $45.45 \pm 10.30$ , mean weight  $78.55 \pm 13.93$ , and mean height  $163.20 \pm 7.96$ . All these patients were nonsmokers.

There was a highly statistically significant difference between the asthma group and the COPD group in R20, whereas no statistically significant difference was found between the two studied groups in R5, X5 (Table 1).

A highly statistically significant difference was found between asthma patients and COPD patients in resistance; 75% of asthmatic patients had increased total airway resistance, mainly proximal, 20% had increased total airway resistance, mainly peripheral, and 5% had normal airway resistance, whereas all COPD patients had increased total airway resistance, mainly peripheral (Table 2).

No statistically significant difference was found between asthma patients and COPD patients in reactance (Table 3).

There was no significant correlation between IOS parameters and FEV<sub>1</sub> in COPD patients or asthmatic patients, but in all patients, there was a statistically significant correlation between FEV<sub>1</sub>, R5 and also between FEV<sub>1</sub> and X5 (Table 4).

There was no significant correlation between IOS parameters and FEV<sub>1</sub>/FVC in COPD patients or asthmatic patients, but in all patients, there was statistically significant correlation between FEV<sub>1</sub>/FVC, R5 and also between FEV<sub>1</sub>/FVC and X5 (Table 5).

**Discussion**

COPD and bronchial asthma are the most frequent respiratory diseases affecting all ages. Both COPD and asthma produce a major disease burden worldwide. Pulmonary function tests are a group of laboratory tests that are used to evaluate the respiratory

functions of the respiratory system to assess the physical fitness and working skills of individuals [7].

IOS technique is a technique designed to measure respiratory impedance, total respiratory resistance, and reactance components at different oscillating frequencies within seconds during simple tidal breathing [8].

The aim of this study was to examine different patterns of changes in resistance, reactance at lower and higher oscillatory frequencies during tidal breathing between stable bronchial asthma and COPD patients using IOS, and to clarify differences in physiological airway mechanics between these two obstructive lung diseases.

In the present study, IOS parameters were compared between two groups. A highly statistically significant difference was found between asthma patients and COPD patients in R20, whereas there was no statistically significant difference between asthma patients and COPD patients in R5, X5.

This was in agreement with Shintarou *et al.* [9] this study was carried out on 95 COPD patients, 52 nonsmoker

**Table 1 Comparison between two groups in terms of impulse oscillation system parameters**

	Asthma (N=20)	COPD (N=20)	t	P-value
R5				
Mean±SD	277.42±68.92	265.04±110.71	0.425	0.674
Range	134.3–437.6	158–540.6		
R20				
Mean±SD	224.91±58.26	135.70±39.31	5.676	0.000
Range	143.1–360.2	79.4–201.4		
X5				
Mean±SD	-0.56±0.33	-0.58±0.33	0.174	0.863
Range	-1.3– -0.1	-1.3– -0.04		

COPD, chronic obstructive pulmonary disease.

**Table 2 Comparison between chronic obstructive pulmonary disease and bronchial asthma in terms of airway resistance**

Resistance	Asthma [n (%)]	COPD [n (%)]	χ <sup>2</sup>	P-value
Normal	1 (5)	0 (0)	26.667	0.000
Mainly proximal	15 (75)	0 (0)		
Mainly distal	4 (20)	20 (100)		

COPD, chronic obstructive pulmonary disease.

**Table 3 Comparison between chronic obstructive pulmonary disease and bronchial asthma in terms of airway reactance**

Reactance	Asthma [n (%)]	COPD [n (%)]	χ <sup>2</sup>	P-value
Normal reactance	3 (15)	1 (5)	1.111	0.292
Reduced Reactance	17 (85)	19 (95)		

COPD, chronic obstructive pulmonary disease.

**Table 4 Correlation between FEV<sub>1</sub> and impulse oscillation system parameters**

	FEV <sub>1</sub>					
	All cases		COPD		Asthma	
	r	P-value	r	P-value	r	P-value
R5	-0.328*	0.039	-0.278	0.235	-0.358	0.122
R20	-0.075	0.644	-0.278	0.235	-0.442	0.051
X5	0.386*	0.014	0.400	0.080	0.256	0.277

COPD, chronic obstructive pulmonary disease; FEV<sub>1</sub>, forced expiratory volume 1. \*Significant.

**Table 5 Correlation between FEV<sub>1</sub>/FVC and impulse oscillation system parameters**

	FEV <sub>1</sub> /FVC					
	All patients		COPD		Asthma	
	r	P-value	r	P-value	r	P-value
R5	-0.479**	0.002	-0.406	0.076	-0.182	0.443
R20	-0.258	0.107	-0.222	0.346	-0.152	0.523
X5	0.469**	0.002	0.390	0.089	0.227	0.335

COPD, chronic obstructive pulmonary disease; FEV<sub>1</sub>, forced expiratory volume 1; FVC, forced vital capacity. \*\*Significant.

asthma patients and 29 healthy nonsmokers older than 60 years of age. They observed that patients with bronchial asthma showed significantly higher values of Rrs20 than those in the control and COPD groups; Rrs5–Rrs20 was increased in the COPD patients in comparison with asthma patients, whereas both asthma and COPD patients showed significantly higher values of Rrs5 and negative changes in Xrs5 than the control group.

These results are not in agreement with Guang-Sheng *et al.* [10], who studied impedance differences between COPD and asthma groups with the same airflow limitation severities. The study included 35 normal patients, 60 COPD patients, and 60 asthma patients, and they found that the impedance indices, including Z5, R5, R20, and R5–R20, which were compared by their logarithmic transformations, were significantly greater in asthma patients than those in the COPD patients at each level of airflow limitation.

This was almost in agreement with Mehdi *et al.* [11]; they compared IOS with spirometry in the diagnosis of obstructive lung diseases. They studied 87 healthy individuals, 87 asthmatic patients, and 56 COPD patients, and they found a significant increase in R5 and R20 in COPD and asthmatic patients in comparison with the controls, whereas X5 decreased in the patient group. The value of high significance in IOS measurements in the COPD group was X5, whereas R20 was the value of high significance in the asthma group.

These results were not in agreement with Yueyue *et al.* [12] in their study of bronchial dilation and IOS in COPD and asthma patients. The study group included 561 patients diagnosed with asthma, 100 patients diagnosed with COPD, and 209 patients with chronic coughing or normal individuals. They found that X5, X25 were correlated significantly with the COPD diagnosis, whereas R5, X35, and Zrs correlated significantly with the diagnosis of bronchial asthma.

The previously mentioned results were not in agreement with the results obtained by Paolo *et al.* [13] in their study on comparison of airway resistance and reactance in asthma and COPD patients; this study was carried out on 34 patients diagnosed with asthma and 48 patients diagnosed with COPD. They found no statistical difference between COPD and asthma patients in R5, R15, and X5.

Similarly, Tan *et al.* [14] found that there was an increase in R5,  $\Delta R5$ –R20 and reduced reactance in

their study of COPD in Vietnamese patients using IOS. The study included 22 patients with COPD and 34 controls. These findings were not in agreement with our study.

These results were in agreement with Hoda *et al.* [15] in a study of the sensitivity of IOS compared with spirometry in the detection of airway obstruction in COPD patients. The study included 80 patients with COPD with varying degrees of severity and 20 healthy nonsmoker individuals as a control group. A statistically significant difference was found between the COPD group and the control group in the use of IOS parameters in assessing airway resistance. It was found that R5 was the most significant IOS parameter for assessing airway resistance in COPD patients compared with R20 and X5.

In this study, a highly statistically significant difference was found between asthma patients and COPD patients in Resistance. It was found that there was an increase in total airway resistance, mainly in the peripheral airways, in all COPD patients, whereas in the asthma group, 15 patients had increased total airway resistance, mainly in the proximal airways, four patients showed an increase in total airway resistance, mainly in the peripheral airways, and the remaining patient had normal resistance.

In this study, no statistical difference was found between asthma patients and COPD patients in reactance. It was found that in the COPD group, 19 patients had reduced airway reactance and only one patient had normal reactance, whereas in the asthma group, about 17 patients had reduced airway reactance and three patients had normal reactance.

This was in agreement with the study carried out by Shintarou *et al.* [9]; they found that COPD patients showed an increase in total airway resistance, mainly peripheral, whereas asthmatic patients showed an increase in total airway resistance, mainly proximal. All COPD and asthma patients had reduced airway reactance.

These results were not in agreement with Guang-Sheng [10] in a study of differences in impedance between COPD and asthma groups with the same airflow limitation severities. They reported that the impedances of asthma patients are greater than those of COPD patients at each airflow limitation level.

This could be attributed to the different study populations. This study included 60 patients with

asthma and 60 COPD patients subdivided into three groups. In each group, patients had the same airflow limitation and patients with FEV<sub>1</sub> less than 35% were excluded. Impedance values were compared between three groups.

Similarly, Yueyue *et al.* [12], who studied bronchial dilation and IOS in COPD and asthma patients, found that there was an increase in peripheral airway resistance in patients with COPD, and this result was in agreement with our study. However, the total airway resistance and viscous resistance were significantly increased in asthma patients, which was not in agreement with our study.

This difference could be attributed to the large sample, long duration (7 years) of this study, and measurement of IOS parameters such as X25, X35 which don't exist in our device.

This was not in agreement with the results reported by Paredi *et al.* [13]; they found that the measurement of whole-breath impedance did not differ significantly between patients with COPD and bronchial asthma as Rrs and Xrs were significantly increase in both patient groups.

This could be attributed to the age of the patients and level of airflow limitation in this study compared with random selection in our study. They assessed 34 patients with asthma with age 49+3 years and FEV<sub>1</sub> 69+4% predicted, 48 patients with COPD with age 64+2 years and FEV<sub>1</sub> 59+3% predicted.

Similarly, Tan *et al.* [14] reported that IOS reactance measurements (X5, Fres) and peripheral resistance ( $\Delta R5-R20$ ) are more diagnostic than proximal resistance (R20) for the changes in pulmonary mechanics caused by airflow obstruction in Vietnamese COPD patients.

In this study, no significant correlation was found between IOS parameters and spirometric parameters in COPD patients or asthmatic patients.

However, in all patients, there was a significant correlation between FEV<sub>1</sub> and R5, X5.

Similarly, FEV<sub>1</sub>/FEV was correlated significantly with R5, X5.

This was not in agreement with Kanda *et al.* [9]; they found that R5 and X5 were correlated significantly

with FEV<sub>1</sub> in COPD, but no significant correlation was found between R5, X5 and FEV<sub>1</sub> in asthmatic patients.

Similarly, Paredi *et al.* [13] found that there was a significant correlation between R5 and FEV<sub>1</sub> in COPD and X5 was correlated significantly with FEV<sub>1</sub> in both COPD and asthma patients. This was in agreement with our study. They also found that there was no correlation between R5 and FEV<sub>1</sub> in bronchial asthma and this was not in agreement with our study.

This could be attributed to the small number of patients in COPD group and asthma group in our study compared with the large sample in the previous two studies, respectively.

This was in agreement with Nikkhah *et al.* [11]; they found a correlation between R5 and X5 with FEV<sub>1</sub> in asthmatic patients, but only R5 showed this correlation with FEV<sub>1</sub> in COPD patients.

This was in agreement with Tan *et al.* [14]; they found that R5, X5, and  $\Delta R5-R20$  were all associated significantly ( $P<0.05$ ) with FEV<sub>1</sub>. Also X5, Fres, and  $\Delta R5-R20$  were correlated significantly with FEV<sub>1</sub>/FVC.

This was in agreement with Hoda *et al.* [15]; they found that R5 was correlated significantly with spirometric parameters.

One of the strengths of this study is that it was carried out on homogenous populations. Patients with infective exacerbations, other respiratory diseases, and those with comorbidities such as diabetes mellitus (DM) were excluded from the study.

#### Study limitation

The duration of the study, which was only 6 months, from January 2017 to June 2017, is a limitation. Also, COPD and asthmatic patients, who were on medications, were asked to stop their medications before undergoing pulmonary function tests. Other comparable studies included a control group in their study, but there was no control group in our study.

#### Conclusion and recommendations

IOS is a noninvasive method that is effective, easy, and useful for the assessment of airway obstruction in chronic obstructive pulmonary disorders. IOS is a valuable tool to differentiate between COPD and

bronchial asthma through variations in airway resistances at different oscillation frequencies. Airway resistance is valuable to differentiate between COPD and bronchial asthma. COPD patients have increased total airway resistance mainly in the distal airways, whereas asthmatic patients have increased total airway resistance mainly in the proximal airways. Reactance is not valuable to differentiate between COPD and bronchial asthma. IOS can differentiate between COPD and bronchial asthma by variation in airway resistance at different oscillation frequencies. Study of groups of patients matched for age and BMI is recommended to differentiate between COPD and bronchial asthma in terms of airway reactance.

#### Financial support and sponsorship

Nil.

#### Conflicts of interest

There are no conflicts of interest.

#### References

- 1 GOLD (2017): *Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease*; P 22. Available at [www.goldcopd.com](http://www.goldcopd.com).
- 2 GINA (2018): *Global strategy for asthma management and prevention*; P 15. Available at [www.ginasthma.com](http://www.ginasthma.com).
- 3 Kanda S, Fujimoto K, Komatsu Y, Yasuo M, Hanaoka M. Evaluation of respiratory impedance in asthma and COPD by an impulse oscillation system. *Intern Med* 2010; **10**:23–30.
- 4 Master Screen, *Viasys Health Care. Instruction manual version 5.1*, September edition, 2006 ; p. 32, 33, 57–61..
- 5 American Thoracic Society/European Respiratory Society Task Force. *Standardization of spirometry. Eur Resp J* 1995; **26**:319–338.
- 6 Smith H, Reinhold P, Goldman M. Forced oscillation technique and impulse oscillometry. Chapter 5. In: Gosselink R, Stam H, editors. *Lung function testing: European respiratory society monograph*. Sheffield, UK: European Respiratory Society. 2005. pp. 548–588.
- 7 Gold WM. Pulmonary function testing. In: Murray JF, Nadel JA, editors. *Textbook of respiratory medicine*. 3rd ed. Philadelphia, PA: Saunders 2000. **3**. pp. 781–871.
- 8 Al-Mutairi SS, Sharma PN, Al-Alawi A, Al-Deen JS. Impulse oscillometry: an alternative modality to the conventional pulmonary function test to categories obstructive pulmonary disorders. *Clin Exp Med* 2007; **7**:56–64.
- 9 Kanda S, Fujimoto K, Komatsu Y, Yasuo M, Hanaoka M, Kubo K. Evaluation of respiratory impedance in asthma and COPD by an impulse oscillation system. *Intern Med* 2010; **49**:23–30.
- 10 Qi GS, Wu H, Yang H, Yuan YP, Xi F, Gu WC. Impedance differences between chronic obstructive pulmonary disease and asthma patients with the same airflow limitation severities. *Int J Clin Exp Med* 2016; **9**:14471–14479
- 11 Nikkiah 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**: 19–25.
- 12 Li Y, Chen Y, Wang P. Application of impulse oscillometry and bronchial dilation test for analysis in patients with asthma and chronic obstructive pulmonary disease. *Int J Clin Exp Med* 2015; **8**:1271–1275.
- 13 Paredi P, Goldman M, Alamen A, Ausin P, Usmani OS, Pride NB, *et al*. Comparison of inspiratory and expiratory resistance and reactance in patients with asthma and chronic obstructive pulmonary disease. *Thorax* 2010; **65**:263–267.
- 14 Tan TX, van Toi V, Khoa TQD, Hanh HDH, Thu TTK, Lan LTT. *Investigating chronic obstructive pulmonary disease (COPD) in Vietnamese patients using impulse oscillometry (IOS)*. 2015; **46**:285–288.
- 15 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. *Egypt J Chest Dis Tuberc* 2016; **66**:395–399.