Impulse oscillometry, an aid or a substitute?

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Introduction In the field of pulmonary medicine, respiratory mechanics and physiology are obviously affected by most pathological lesions and diseases, either primary disease or part of systemic ones. In the era of rheumatoid arthritis (RA), airway abnormality and interstitial lung pneumonia and/or fibrosis are the most common findings that face physicians during the disease course and affect morbidity, survival, and quality of life of patients with RA. Impulse oscillometry (IOS) is a noninvasive technique that needs minimal patient cooperation, which makes it suitable for any age including even children and can be performed by most patients.

Aim of the work To describe the respiratory measures done by IOS in patients with RA and to correlate them with those measured by spirometry.

Patients and methods A total of 60 patients with RA were recruited in this cross-sectional observational study. They were investigated via pulmonary function assessments, including spirometry and IOS, to measure forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), and FEV1/FVC, and maximal expiratory flow at 25% (MEF 25%) in addition to R5% of predicted, R20% of predicted, R5–20, X5, and area under the curve.

Results IOS measures indicated increased airway resistance (R5%, R20%, and R5–20) with decreased lung reactance (X5). Moreover, a positive correlation between disease duration and X5, between X5 and area under the curve and each of FEV1%, FVC%, and MEF 25%, whereas a negative correlation between R5–20 and each of FEV1%, FVC%, and MEF 25%.

Conclusion IOS is an easy and rapid maneuver that requires minimal patient cooperation. It can identify lung affection in those who have mild or even normal spirometric changes. It is just a good screening test in patients with RA to detect early pathophysiologic lung changes. However, it needs further investigations to clarify the mechanism of these changes.

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Introduction

In the field of pulmonary medicine, respiratory mechanics and physiology are obviously affected by most pathological lesions and diseases, either primary disease or part of systemic ones [1].

Rheumatoid arthritis (RA) is one of the chronic autoimmune inflammatory disorders that not only affects the joints but also has a significant effect on most body systems, with different manifestations according the disease stage [2–4]. Of extra-articular manifestations, pulmonary affection is a major participant to morbidity and mortality, and not rarely, pulmonary symptoms can herald articular symptoms [5].

In the era of RA, airway abnormality and interstitial lung pneumonia and/or fibrosis are the most common findings that physicians face during the disease course and affect morbidity, survival, and quality of life of patients with RA [6,7].

Some extraordinary methods have been used to evaluate disease severity and degree of lung affection, including chest radiology, which needs an advanced pathologic changes in the disease course to diagnose [8], and spirometric pulmonary function tests, which necessitates patients' cooperation during forceful inspiratory and expiratory maneuvers of the test [9]. Moreover, all these tests are used in advanced disease stages with less response to treatment.

Forced oscillation technique (FOT) is not a new method. It was determined over the past years by Dubois *et al.* [10] to be used for assessment of respiratory mechanics by adding pressure fluctuation to normal breathing phases [11].

Impulse oscillometry (IOS) is a variety of FOT that was developed later to use less range of definite frequencies. It is an apparatus with a loudspeaker that generates impulses that are superimposed on persons' tidal breathing to travel throughout all airways (low frequencies reach far distance till alveoli

to be reflected back, whereas high frequencies are reflected from large airways), and according to pressure and flow changes, lung mechanics are evaluated and assessed [12].

It measures respiratory impedance with its two components: total resistance and reactance [13]. Total airway resistance is identified using low frequency, 5 Hz (R5), whereas central resistance is specified at high frequency, 20 Hz (R20). Discrepancy between R5 and R20 (R5–R20) is used to measure small airways resistance [14]. On the contrary, reactance at 5 Hz (X5) is a reflection of compliance [15].

Moreover, IOS is a noninvasive technique that needs minimal patient cooperation that make it suitable for any age including even children and can be performed in most patients even with advanced stages of the disease [11].

Aim of the work

The purpose of the present study was to describe the respiratory measures done by IOS in patients with RA and to correlate them with those measured by spirometry.

Patients and methods

Study design and settings

This study was a cross-sectional observational study that was conducted at Chest Department, Faculty of Medicine, Tanta University, starting from March 2017 to May 2018.

Diagnosis of patients with RA was carried out at Internal Medicine as well as Physical Medicine, Rheumatology and Rehabilitation outpatient clinics.

Patients

A total of 60 patients with RA were recruited in this study according to inclusion and exclusion criteria.

Inclusion criteria were patients diagnosed with RA. Diagnosis of patients with RA was done according to American College of Rheumatology/European League Against Rheumatism 2010 RA classification criteria [16].

Exclusion criteria were other chronic respiratory diseases [asthma, chronic obstructive pulmonary disease (COPD), bronchiectasis, pneumonia, interstitial fibrosis, bronchogenic carcinoma, etc.] and patients with cardiac diseases.

Methods

All participants were subjected to the following:

(1) Patients with RA were assessed clinically by complete history taking (age, duration of the disease, smoking history, therapeutic history, course of the disease, and chest complaints) and general and locomotor system examination.
(2) Disease activity score (DAS) of RA was calculated according to DAS28 [17].
(3) Complete blood picture, erythrocyte sedimentation rates, C-reactive protein, rheumatoid factor titer, and anti-cyclic citrullinated peptide.
(4) Plain chest radiography posteroanterior view and computed tomography (CT) chest if indicated.
(5) Pulmonary functions assessment:
    (a) Ventilatory function tests, including forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1) and FEV1/FVC, and maximal expiratory flow at 25% (MEF 25%) [18,19], using computerized spirometry limb of Master Lab-IOS Unit [20].
    (b) IOS measurements, including R5% of predicted, R20% of predicted, R5–20, X5, and area under the curve (AX), were done using IOS limb of Master Lab-IOS Unit [1,21]. Spirometry and IOS were done using device Master Lab-IOS Unit (Master Screen IOS 2001, version 4.5; Erich Jaeger GmbH, Hoechberg, Germany).

Informed consents were taken from patients for the procedures and for usage of their medical data.

The ethical committee approved the study protocol.

Statistical analysis

Data were analyzed using sigma-plot for Windows version 11.0, build 11.0.0.77, copyright 2008 systat software, product of GmbH, Germany. Student's *t* test was used to compare mean of the two groups. Quantitative data were presented as mean±SD. Correlation was done using Spearman's correlation test.

Most data were normally distributed, whereas others were nonnormally distributed (such as X_5% and R_5).

Results

The 60 enrolled patients were allocated into two groups according to spirometric readings: group 1 included 26 patients with normal spirometric readings, whereas group 2 included 34 patients with abnormal spirometry (Table 3).

Table 1 Demographic data and diseased activity index in patients with rheumatoid arthritis

Variables	Group 1 (*N*=26)		Group 2 (*N*=34)	
	Mean±SD	Minimum–maximum	Mean±SD	Minimum–maximum
Age	50.08±13.39	31–70	47.12±11.74	24–68
Disease duration	11.69±5.23	5–25	8.94±3.83	4–20
DAS28 [*n* (%)]				
Clinical remission				
Below 2.6	2 (7.70)		8 (23.53)	
Low disease activity				
2.6–3.2	4 (15.38)		11 (32.35)	
Moderate disease activity				
3.2–5.1	12 (46.15)		8 (23.53)	
High disease activity				
Above 5.1	8 (30.77)		7 (20.59)	
RF positivity [*n* (%)]	20 (76.92)		19 (55.88)	

DAS28, disease activity score 28; RF, rheumatoid factor.

All patients were females. Moreover, there was no significant difference between the two groups regarding age and disease duration (Table 1).

Most patients in group 1 had moderate (46.15%) disease activity, whereas in group 2, most of them had low (32.35%) disease activity. Moreover, most of the patients were rheumatoid factor positive (76.92 and 55.88%) in groups 1 and 2, respectively (Table 1). Methotrexate and leflunomide were the main two medications received by patients in groups 1 and 2 (57.69 and 35.29%, respectively) (Table 2).

There were no significant differences between the two groups regarding FEV1/FVC, R5%, R5 actual, and AX, whereas there were significant differences between the two groups regarding FVC%, FEV1%, MEF 25%, R20%, R20 actual, X5%, and X5 actual (Table 3).

In group 1, mean R5% (used for small and large airways) was 185.53±96.89 referring to airway obstruction, whereas mean R20% (used for large airways) was 128.78±39.52 (within normal), which is suggestive of small airways obstruction (R5–20 was 0.2962±0.26). However, in group 2, R5% and R20% were 197.29±51.01 and 180.88±35.82, respectively, denoting large and small airways affection (R5–20 was 1.63±7.67) (Table 3).

Spirometry did not reveal changes in group 1 (except MEF 25%, which identified small airway affection in 38.46% of patients), whereas IOS identified increased total and large airway resistance in 46.15 and 30.77%, respectively, and abnormal reactance in 53.85% of patients, with abnormal AX actual in 22 (84.62%) patients.

In group 2, spirometry identified airway obstruction, restriction, and mixed affection in 32.35, 44.12, and 23.53% of patients, respectively, whereas IOS showed increased large and all airway resistance in 76.47 and 82.35% of patients, respectively, with abnormal reactance (X5 and AX actual) in all patients (Tables 4 and 5).

Table 2 Received drug for patients in both groups

Medications	Group 1 (*N*=26) [*n* (%)]	Group 2 (*N*=34) [*n* (%)]
Methotrexate	15 (57.69)	7 (20.59)
Leflunomide	6 (23.08)	12 (35.29)
Hydroxychloroquine	2 (7.69)	8 (23.53)
Corticosteroids	2 (7.69)	5 (14.71)
NSAIDs	1 (3.85)	2 (5.88)

There was negative correlation between R5–20 (small airway obstruction) and each of FEV1%, FVC%, and MEF 25% separately but a positive correlation between actual X5 and AX and each of FEV1%, FVC%, and MEF 25% separately (Tables 6 and 7).

Discussion

RA is a chronic, systemic, inflammatory autoimmune disease characterized by inflammation of the synovial membranes of the diarthrodial joints, which may be followed by cartilage destruction, bone erosion, and weakening and destruction of the ligaments, tendons, and joint capsules. RA is a systemic disease, often associated with extra-articular manifestations [22].

Pulmonary complications are common and directly responsible for 10–20% of all mortality. Being associated with unfavorable prognosis, it becomes mandatory to detect subclinical pulmonary involvement in patients with RA for adequate long-term treatment [23].

Table 3 Comparison of spirometric and impulse oscillometry measures between the two studied groups

	Group 1 (*N*=26)			Group 2 (*N*=34)			*t*	*P*
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum		
Age	50.08±13.39	31	70	47.12±11.74	24	68	0.91	0.366
Disease duration	11.69±5.23	5	25	8.94±3.83	4	20	2.359	0.022
FVC%	102.61±31.43	85.06	208	77.47±7.66	59.12	89.27	4.504	<0.001
FEV1%	101.28±28.45	85.7	195.2	73.7203±7.94	56.43	88.32	5.394	<0.001
FEV1/FVC	85.08±7.96	74.95	101.51	72.84±14.31	45.28	103.03	3.916	<0.001
MEF 25%	71.19±37.05	25.3	162.7	51.71±18.46	28.10	81.7	2.668	0.010
R5% predicted	185.53±96.89	98.5	404.6	197.29±51.01	128.0	304	–0.607	0.546
R5 actual (kPa/l/s)	0.71±0.39	0.37	1.61	0.83±0.23	0.37	1.15	–1.503	0.138
R20% predicted	128.78±39.52	86.5	209	180.88±35.82	115.0	234	–5.339	<0.001
R20 actual (kPa/l/s)	0.41±0.13	0.3	0.71	0.51±0.14	0.31	0.82	–2.759	0.008
R5–20 actual	0.2962±0.26	0.07	0.90	1.63±7.67	–0.15	45.0	–0.883	0.381
X5% predicted	430.81±528.77	–166.7	1411	809.12±378.84	307.2	1409.	–3.23	0.002
X5 actual	–0.125±0.132	–0.35	0.15	–0.31±0.13	–0.63	–0.16	5.541	<0.001
AX	1.66±1.66	0.23	5.12	2.13±1.71	0.68	6.04	–1.069	0.290

Comparison is significant if *P* value less than or equal to 0.05. AX, area under the curve; between X5 Hz and cross-point of the curve to horizontal line; FEV1%, forced expiratory volume in 1 s of FVC test; FVC%, forced vital capacity; MEF 25%, maximal expiratory flow at 25% of forced vital capacity. R5%, predicted resistance at frequency 5 Hz. R5 act, actual measure of resistance at frequency 5 Hz. R20%, predicted resistance at frequency 20 Hz. R20 act, actual measure of resistance at frequency 20 Hz. R5–20, actual lung resistance when subtraction resistance at frequency 5 Hz minus resistance at frequency 20 Hz. X5%, predicted lung reactance at frequency 5 Hz. X5 act, actual measure of lung reactance at frequency 5 Hz.

Table 4 Percentage of spirometry abnormalities in both groups

	Group 1 (*N*=26) [*n* (%)]	Group 2 (*N*=34) [*n* (%)]	Total (*N*=60) [*n* (%)]
FEV1%, FVC%, FEV/FVC			
Normal	26 (0)	0 (0)	26 (43.33)
Obstructive	0 (0)	11 (32.35)	11 (18.33)
Restrictive	0 (0)	15 (44.12)	15 (25)
Mixed	0 (0)	8 (23.53)	8 (13.33)
MEF 25% abnormality	10 (38.46)	22 (64.71)	32 (53.33)

FEV1%, forced expiratory volume in 1 s of FVC test; FVC%, forced vital capacity; MEF 25%, maximal expiratory flow at 25% of forced vital capacity.

Table 5 Percentage of impulse oscillometry abnormalities in the two studied groups

	Total number and percentage of normal IOS measures [*n* (%)]	Total number and percentage of abnormal IOS measures [*n* (%)]
Group 1 (26)		
R5% of predicted	14 (53.85)	12 (46.15)
R20% of predicted	18 (69.23)	8 (30.77)
X5(kPa/l/s)	14 (53.85)	12 (46.15)
AX	4 (15.38)	22 (84.62)
Group 2 (34)		
R5% of predicted	6 (17.65)	28 (82.35)
R20% of predicted	8 (23.35)	26 (76.47)
X5(kPa/l/s)	0 (0)	34 (100)
AX	0 (0)	34 (100)

AX, area under the curve; between X5 Hz and cross-point of the curve to horizontal line; IOS, impulse oscillometry. R5%, predicted resistance at frequency 5 Hz. R5 act, actual measure of resistance at frequency 5 Hz. R20%, predicted resistance at frequency 20 Hz. R20 act, actual measure of resistance at frequency 20 Hz. R5–20, actual lung resistance when subtraction resistance at frequency 5 Hz minus resistance at frequency 20 Hz. X5%, predicted lung reactance at frequency 5 Hz. X5 act, actual measure of lung reactance at frequency 5 Hz.

Table 6 Correlation between spirometry and impulse oscillometry measures in group 1

	FVC%	FEV1%	MEF 25%	R5%	R5 act	R20%	R20 act	R5–20	X5 act	X5%	AX act
Disease duration											
r	0.646	0.0551	–0.525	–0.58	–0.530	0.677	–0.558	0.0721	0.105	–0.457	–0.239
P	0.0004	0.787	0.006	0.0019	0.0056	0.0001	0.0032	0.723	0.608	0.0193	0.235
FVC%											
r		0.470	–0.0604	–0.330	–0.336	–0.407	–0.437	–0.0803	0.121	–0.264	0.132
P		0.0156	0.766	0.0986	0.0922	0.0392	0.0256	0.693	0.553	0.191	0.518
FEV1%											
r			0.627	–0.168	–0.181	0.0605	–0.080	–0.337	0.487	–0.261	–0.107
P		–	0.000615	0.408	0.373	0.766	0.693	0.0915	0.0118	0.194	0.599
MEF 25%											
r				0.258	0.193	0.571	0.376	–0.310	0.489	–0.0385	–0.0110
P			–	0.200	0.341	0.00241	0.0576	0.122	0.0114	0.849	0.955

AX, area under the curve; between X5 Hz and cross-point of the curve to horizontal line; FEV1%, forced expiratory volume in 1 s of FVC test; FVC%, forced vital capacity; MEF 25%, maximal expiratory flow at 25% of forced vital capacity. R5%, predicted resistance at frequency 5 Hz. R5 act, actual measure of resistance at frequency 5 Hz. R20%, predicted resistance at frequency 20 Hz. R20 act, actual measure of resistance at frequency 20 Hz. R5–20, actual lung resistance when subtraction resistance at frequency 5 Hz minus resistance at frequency 20 Hz. X5%, predicted lung reactance at frequency 5 Hz. X5 act., actual measure of lung reactance at frequency 5 Hz. Positive correlation: if two variables tend to increase together, negative correlation: one variable tends to decrease while the other increases. Significant relationship if *P* values equal or less than 0.050.

Table 7 Correlation between spirometry and impulse oscillometry measures in group 2

	FVC%	FEV1%	MEF 25%	R5%	R5 act	R20%	R20 act	R5–20	X5 act	X5%	AX act
Disease duration											
r	–0.243	–0.437	–0.390	0.166	–0.135	0.0185	–0.116	0.122	–0.247	–0.259	–0.0750
P	0.166	0.0101	0.0229	0.345	0.938	0.916	0.512	0.488	0.157	0.138	0.671
FVC%											
r		0.0246	0.359	–0.159	–0.155	–0.263	0.0653	–0.167	0.0459	0.0740	0.226
P		0.889	0.0369	0.368	0.378	0.132	0.712	0.343	0.794	0.675	0.197
FEV1%											
r			0.424	–0.090	–0.055	–0.279	–0.050	0.0381	0.247	–0.235	–0.140
P		–	0.0128	0.611	0.757	0.109	0.774	0.829	0.157	0.180	0.426
MEF 25%											
r				0.255	0.0933	–0.680	–0.243	0.227	0.240	0.144	–0.137
P			–	0.144	0.597	0.0000	0.165	0.195	0.169	0.415	0.436

AX, area under the curve; between X5–Hz and cross-point of the curve to horizontal line; FEV1%, forced expiratory volume in 1 s of FVC test; FVC%, forced vital capacity; MEF 25%, maximal expiratory flow at 25% of forced vital capacity. R5%, predicted resistance at frequency 5 Hz. R5 act, actual measure of resistance at frequency 5 Hz. R20%, predicted resistance at frequency 20 Hz. R20 act, actual measure of resistance at frequency 20 Hz. R5–20, actual lung resistance when subtraction resistance at frequency 5 Hz minus resistance at frequency 20 Hz. X5%, predicted lung reactance at frequency 5 Hz. X5 act, actual measure of lung reactance at frequency 5 Hz. Positive correlation: if two variables tend to increase together, negative correlation: one variable tends to decrease while the other increases. Significant relationship if *P* values equal or less than 0.050.

IOS is a simple maneuver to detect changes in patients with respiratory disease especially those affecting airways. IOS measures give many parameters to interpret; R5 readings indicate all airway resistance, whereas R20 specifies proximal airway resistance. X5 is related to the interactive and capacitive pressure loss. The balance point where X5 crosses the horizontal axis of frequency is termed Fres; hence, the reactance area between 5 Hz and Fres is designed as the AX [24,25].

In the present study, 60 patients with RA were studied using spirometry and IOS maneuvers to detect pathophysiological changes in those patients and the role of IOS in identification of these changes in correlation with spirometry.

In our study, all patients were female, with mean age of 50.08±13.39 and 47.12±11.74 years in group 1 and 2, respectively; this was in coordnance with some studies (50.75±11.13 and 44.78±10.99, respectively) [1,26], whereas others recorded different ages (65 and 65.5 ±10.1, respectively) [27,28]. The average onset of RA is between the ages of 30 and 60 years, with more prevalence in females.

Patients with RA in the present study had disease duration ranged from 5 to 25 years in group 1 and from 4 to 20 years in group 2, with mean duration of 11.69±5.23 and 8.94±3.83 in groups 1 and 2, respectively, and all patients had active RA, with mean DAS28 of 3.590±1.593.

Anderson *et al.* [29] recommend DAS28 counts for measuring RA disease activity because it is an accurate reflection of disease activity, is sensitive to change, has remission criteria, is feasible to perform in clinical settings, and discriminates well between low, moderate, and high disease activity states. Moya Alvarado and Laiz [30] concluded that DAS28 has consolidated as a fundamental tool to evaluate RA activity. In contrast with the American College of Rheumatology scores, it is a continuous measurement, lineal, with no need for prior point of reference.

Patients in group 1 had normal spirometric functions except MEF 25%, which was abnormal in 38.46% of patients, whereas IOS in this group succeeded to discover large airway affection (R20%), increased all airway resistance (R5%) and decreased reactance with increase AX in 30.77, 46.15, and 84.62 of patients, respectively.

In group 2, spirometric measures denoting obstructive, restrictive, and mixed pulmonary changes in the studied patients, with 32.35, 44.12, and 23.53%, respectively, whereas IOS measures identified higher percentage of proximal airway obstruction and all airway resistance in 76.47 and 82.35%, respectively, with decrease reactance in 100% of patients.

Habib *et al.* [31] studied 40 patients with RA with less than 2 years of disease duration and revealed 45% of patients had abnormalities in CT scan and/or pulmonary function tests, whereas only 10% have clinically significant symptoms.

Cavagna *et al.* [32] and also Assayag *et al.* [33] revealed in their two relative studies that most patients with RA having interstitial lung disease had restrictive pulmonary function, hypoxemia, and impaired diffusing capacity with poor prognosis in their follow-up.

Studies tried to show a relationship between small airways affection and RA are usually perplexed by the presence of interstitial lung pathology and diagnosed mainly by high-resolution CT scan [34]. In a relative study by Demoruelle *et al.* [35] concluded that restrictive and obstructive spirometric lung functions were found in 12 and 26.32%, respectively, while CT scan diagnosed airway affection in 64.91% of patients.

Guan *et al.* [36] reported the importance of IOS in identifying early changes in small airways in bronchiectasis patients and airway impedance (Z5), and R5 could be used interchangeably for resistance assessment in airway impedance.

In the present study, a positive correlation was found between disease duration and X5 and R5–20 and also between MEF 25% and X5, whereas a negative correlation was found between R5%, R5–20, FEV1%, and FVC%, denoting sensitivity of IOS in detecting small airway narrowing and increased peripheral lung resistance in addition to decrease impedance and reactance in patients with RA.

Mori *et al.* [37] reported usefulness of AX and X5 in discriminating respiratory resistance and reactance in reversible and irreversible airway obstructive diseases, whereas Shirai *et al.* [38] studied $R_{\text{frequency}}$ and X5 of lung impedance and their role in asthma phenotyping. Using FOT, Mikamo *et al.* [39] reported a good correlation of AX with other investigatory methods for peripheral lung reactance and resistance, in addition to FOT usage as a good global assessment of airways diseases. van Noord *et al.* [40] reported increased Rrs and reduced Xrs in patients with ILDS, but they could not certify if these changes were owing to parenchymal or severe airway affection.

X5 and/or AX measurements reflect reactance portion of lung impedance (Z), so when X5 decreases (more negativity), it indicates increased peripheral lung resistance and low reactance because of using low frequencies, and these findings were observed in the present study denoting parenchymal affection (probably because of some degree of interstitial lung fibrosis), in addition to peripheral airway obstruction, which had a role in decreased AX and more X5 negativity with increased R5%. However, unfortunately this cannot single out the explanation for this X5 decrement (because of peripheral airway or parenchymal affection), necessitating further investigations.

In a study by Mori *et al.* [41] and also similar one by Sugiyama *et al.* [42], they reported decreased *X* values (mainly X5) in patients with interstitial lung diseases, especially in inspiration, which has more negativity than in expiration, in contrast to patients with COPD, which had decreased values in expiration that is more negative than in inspiration.

Tomalak *et al.* [43] reported a strong correlation between R5, R5–R20, and FEV1 (–0.503, –0.570, and –0.673, respectively).

El-Naggar *et al.* [44] showed no significant correlation between FEV1% and R5 and no significant difference

between spirometry and IOS in early airway obstruction detection in smokers.

Patients with RA have pulmonary complications that usually start insidiously and progress silently, so most of them seek medical advice in advanced stages of pulmonary affection, with late time for proper management. It necessitates accurate investigatory method to detect these changes in early controllable stage of the disease to be assessed and investigated by further confirmatory methods.

Many studies revealed the changes in some IOS parameters (reflecting airway affection) in patients with airway diseases such as asthma and COPD.

Unfortunately, there are poor number of research studies that tried to explore changes of IOS parameters (reflecting parenchymal, reactance, and impedance affection) in patients with diseases affecting the lung parenchyma.

One of limitations of the present study is paying no attention to the effects of drugs that patients receive and their effect on pulmonary functions.

Second limitation is lacking of other pulmonary investigations that reflect diffusion and peripheral airway affection to be correlated with X5 and AX.

Another limitation is the limited number of cases included in the study.

Conclusion

IOS is an easy maneuver with minimal need for patients cooperation, requires only tidal breathing, and can be completed within 5–15 min. It is able to identify advanced stage of lung disease in those who have mild spirometry changes. IOS can be used perfectly as an early screening technique to identify proximal and distal pulmonary tissue affection even before spirometry changes and detects lung resistance and reactance changes. IOS can be used as a screening tool for patients with RA to discover early pathophysiologic lung changes. In addition, it helps selection of patients needing further investigations to confirm the cause of increase lung resistance in patients with RA.

Recommendation

IOS is a simple, sensitive, and rapid maneuver to be used in patients with diseases affecting the lung airway and/or parenchyma. More studies are required to clarify the role of IOS in early diagnosis and screening of lung diseases especially parenchymal affection and how to discriminate between it and airway affection. The use of IOS in follow-up still needs further evaluation to reveal disease progress and/or response to treatment.

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Conflicts of interest

There are no conflicts of interest.

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