Int J Clin Exp Med 2015;8(1):1271-1275
www.ijcem.com /ISSN:1940-5901/IJCEM0002365

Original Article

Application of impulse oscillometry and bronchial dilation test for analysis in patients with asthma and chronic obstructive pulmonary disease

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Received September 7, 2014; Accepted December 1, 2014; Epub January 15, 2015; Published January 30, 2015

Abstract: Impulse oscillometry (IOS) is a good method for measuring airway resistance. The aim of this study was to assess the diagnostic contribution of IOS combined with bronchial dilation test (BDT) when distinguishing between patients with asthma and those with chronic obstructive pulmonary disease (COPD). 870 were enrolled in the study including 561 patients with asthma, 100 patients with COPD and 209 patients with chronic coughing or normal subjects. All the participants underwent routine pulmonary function tests, IOS and BDT examination. And IOS examination was before and after BDT. IOS parameters (R5, R20, R25, R35, X5, X20, X25, X35, Fres, Zrs & RP) and forced expiratory volume in one second (FEV1) were recorded. Receiver operating characteristics (ROC) curve analysis was performed to evaluate the diagnostic ability to differentiate asthma and COPD. The discriminative power of the various parameters studied was determined by means of ROC curves: the area under the curve (AUC), sensitivity and specificity. The X5, X20, X25, X35, Fres, Zrs and Rp correlated better with COPD. In particular, X5, Fres and X25 have been found to be significantly correlated with COPD. The diagnostic efficiency of X5, Fres and X25 when diagnosis COPD, expressed by ROC curve parameters, was as follows: AUC (0.725, 0.730, 0.724), sensitivity (67%, 77%, 83%) and specificity (68%, 65%, 58%), respectively. The diagnostic efficiency of Zrs, R5 and X35 when diagnosis asthma, expressed by ROC curve parameters, was as follows: AUC (0.721, 0.710, 0.695), sensitivity (62%, 72%, 53%) and specificity (72%, 61%, 76%), respectively. Our findings show, that X5, X25 and Fres may be useful for predictions and evaluations for COPD. And R5, X35 and Zrs may provide useful IOS parameters for asthma. IOS combined BDT could be useful diagnostic and differential diagnosis between asthma and COPD.

Keywords: Impulse oscillometry system (IOS), chronic obstructive pulmonary disease (COPD), asthma

Introduction

Asthma and chronic obstructive pulmonary disease (COPD) are chronic inflammatory disease of the airways and cause a major public health concern [1, 2]. Asthma is a chronic inflammatory disease of the airways, usually starting in childhood, characterized by reversible airflow obstruction [3]. On the contrary, COPD is typically caused by tobacco smoking and displays incompletely airflow obstruction [4]. Obstruction is usually intermittent and reversible in asthma, but is progressive and irreversible in COPD [5]. Therefore, asthma and COPD may overlap and converge, especially in older people [6].

Bronchial dilation test (BDT) was used for the diagnosis and differential diagnosis between asthma and COPD [7]. In BDT, forced expiratory volume in the first second (FEV1) was used as a measure of evaluation [8]. However, BDT may be affected by many factors, such as the state of systemic in patients, patients' cooperation. Sometimes, the result does not fully reflect the degree of patients' airway obstruction.

Impulse oscillometry (IOS) is a good method for measuring airway resistance. In contrast to BDT, a major advantage in IOS is its ability to perform these measurements in a noninvasive and relatively effort independent during spontaneous normal tidal breathing [9, 10]. Therefore, the advantage of IOS is that requires minimal patient cooperation. It measures both small and large airways resistance and resonance capacitance of the lung [11]. Due to detecting

Table 1. AUC about IOS parameters: predictive value of asthma and COPD

IOS parameters	Before BDT		After BDT		BDT difference§	
	Asthma	COPD	Asthma	COPD	Asthma	COPD
R5	0.617	0.593	0.505	0.686	0.710*	0.613
R20	0.518	0.497	0.534	0.576	0.580	0.621
X5	0.615	0.656	0.492	0.725*	0.684	0.517
Fres	0.656	0.627	0.533	0.730*	0.694	0.616
Zrs	0.617	0.614	0.505	0.713*	0.721*	0.600
R25	0.507	0.512	0.536	0.553	0.572	0.589
R35	0.498	0.526	0.546	0.546	0.580	0.582
X20	0.650	0.625	0.533	0.717*	0.692	0.607
X25	0.644	0.627	0.536	0.724*	0.679	0.622
X35	0.659	0.622	0.543	0.706*	0.695	0.606
Rp	0.592	0.655	0.506	0.715*	0.669	0.601

*AUC > 0.7. §BDT difference: the difference between after BDT and before BDT.

Table 2. Sensitivity and specificity of IOS predictive indexs for asthma and COPD

IOS predictive indexs	Sensitivity	Specificity
Asthma		
R5	0.72	0.61
X35	0.53	0.76
Zrs	0.62	0.72
COPD		
X5	0.67	0.68
X25	0.83	0.58
Fres	0.77	0.65

large and small airways diseases separately, IOS has been applied in asthma diagnosis and management [12-14].

In this study, we used IOS before and after BDT to examine whether IOS parameter differ between patients with asthma and patients with COPD and to evaluate the value of diagnosis and differential diagnosis.

Materials and methods

Study population

870 participants (561 patients with asthma, 100 patients with COPD and 209 patients with chronic coughing or normal subjects) who visited the Department of Respiratory Medicine of the 306th Hospital of PLA between February 2002 and December 2009 were enrolled in the study. This study included 552 males and 318 females, ranging from 15 years to 98 years old (mean age, 50.5 ± 18.8 years old). The diagnosis of asthma and COPD were established according to American Thoracic Society (ATS) criteria. This study was conducted with approval from the Ethics Committee of 306 Hospital of PLA. Written informed consent was obtained from all participants.

Bronchial dilation test (BDT)

All subjects withheld short- and long-acting bronchodilators 6 and 24 hours, respectively, prior to study visits. FEV1 at 15 minutes after inhaling 200 μg salbutamol is the best choice as it is highly efficient and causes less side effects. An absolute increase of FEV1 200 ml or improving rate FEV1 12% should be the positive standard of diagnosing asthma after patients inhaling 200 μg salbutamol. Without the positive results, combined with the clinical symptoms, patients were diagnosed COPD (FEV1 < 200 ml or improving rate FEV1 < 12%).

Impulse oscillometry (IOS)

IOS parameters were collected before conventional spirometry using the MasterLab IOS System (Erich Jaeger Co., Würzburg, Germany). The pneumotachometer was calibrated daily using a 3 litre syringe, and pressure calibration was checked weekly with a reference resistance (0.2 kPa/l/s). The individuals wore a nose clip and a manufacturer-provided oval hard plastic mouthpiece to prevent expired air from escaping. They were also asked to support their cheeks with their hands to decrease shunt compliance. Artifacts caused by coughing, breath-holding, swallowing, and vocalization were not included. The impedance (Zrs) representing a complex airway resistance, which includes two components, the real resistance (Rrs) and the imaginary reactance (Xrs), has also been determined. The frequency range of the signal was from 0 to 100 Hz, and we recorded R5-35 and X5-35. Rrs at 5 and 20 Hz represent the low (total resistance) and high (central resistance) frequency range, respectively. The parameters evaluated were R5, R20, R25, R35, X5, X20, X25, X35, resonant frequency (Fres) and peripheral resistance (Rp). Reported results are averages of 3-4 technically acceptable periods of 40-60 s of tidal breathing.

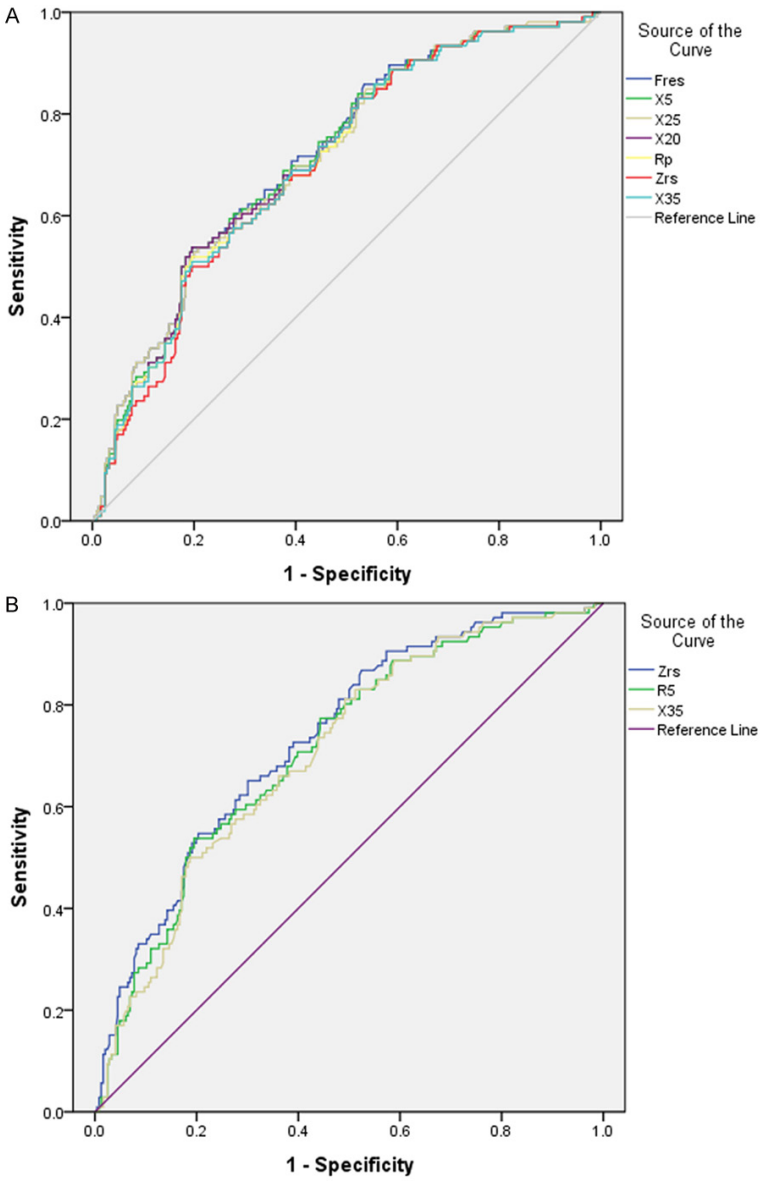

Figure 1. Receiver Operating Characteristic (ROC) curves for distinguishing COPD (A) and asthma (B). The diagnostic efficiency of X5, Fres and X25 when diagnosis COPD, expressed by ROC curve parameters, was as follows: AUC (0.725, 0.730, 0.724), sensitivity (67%, 77%, 83%) and specificity (68%, 65%, 58%), respectively. The diagnostic efficiency of Zrs, R5 and X35 when diagnosis asthma, expressed by ROC curve parameters, was as follows: AUC (0.721, 0.710, 0.695), sensitivity (62%, 72%, 53%) and specificity (72%, 61%, 76%), respectively.

Statistics

Data were analyzed using version 11 of the SPSS statistical software. Data are given as mean ± standard deviation (SD). Receiver operating characteristics (ROC) curve analysis was performed to evaluate the diagnostic ability to differentiate asthma and COPD. The discriminative power of the various parameters studied was determined by means of ROC curves: the area under the curve (AUC), sensitivity and specificity. The ROC curves with AUC were plotted to demonstrate sensitivity and specificity of the evaluated IOS. *P*-value < 0.05 were considered statistically significant.

Results

A total of 870 participants were enrolled into this study. Among 870 patients, 561 were diagnosed with asthma, 100 were diagnosed with COPD and 209 patients with chronic coughing or normal subjects. ROC curves were constructed for each of the IOS measurements. For 209 patients with chronic coughing or normal subjects, were just negative controls when established the optimal cut-off values for IOS parameters in ROC curves to diagnose asthma and COPD.

The X5, X20, X25, X35, Fres, Zrs and Rp correlated better with COPD. In particular, X5, Fres and X25 have been found to be significantly correlated with COPD. The X5 had AUC of 0.725 and produced a sensitivity of 67% and a specificity of 68% for the diagnosis of COPD. The Fres had AUC of 0.730 and produced a sensitivity of 77% and a specificity of 65% for the diagnosis of COPD. The X25 had AUC of 0.724 and produced a sensitivity of 83% and a specificity of 58% for the diagnosis of COPD (**Tables 1** and **2**).

The Zrs had AUC of 0.721 and produced a sensitivity of 62% and a specificity of 72% for the diagnosis of asthma. The R5 had AUC of 0.710 and produced a sensitivity of 72% and a specificity of 61% for the diagnosis of asthma. The

X35 had AUC of 0.695 and produced a sensitivity of 53% and a specificity of 76% for the diagnosis of asthma (**Tables 1** and **2**). IOS parameters had predictive effects if AUC is higher than 0.7. Diagnostic performance of IOS parameters were shown in **Figure 1**. Therefore, X5, X20, X25, X35, Fres, Zrs and Rp correlated better with COPD. The X5, X25 and Fres have clearly the best predictive value for COPD. For asthma, R5, X35 and Zrs have clearly the best predictive value.

Discussion

Many clinical studies have reported that IOS has reference values and high reproducibility in chronic pulmonary diseases [15]. Asthma and COPD are prevalent chronic pulmonary diseases [16]. COPD is characterized by chronic airway inflammation and/or airflow limitation and asthma is characterized by airway obstruction [17]. Generally, reversibility of airflow limitation is incomplete in COPD, while that in asthma can be complete [18]. Therefore, asthma and COPD may overlap and converge [19, 20]. Our study was to explore the application and clinical value of combining IOS and BDT for differential diagnosis between asthma and COPD.

In the present study, 870 participants were categorized in three groups: 1) 561 patients with asthma; 2) 100 patients with COPD; 3) 209 patients with chronic coughing or normal subjects. After inhaling salbutamol, IOS and spirometry measurement was detected by devices. Compared with the control group (chronic coughing or normal subjects), the results showed that IOS was useful to distinguish between patients with asthma and those with COPD. So that it seems more to apply for the target populations in medical procedures.

In IOS parameters, X5, X20, X25, X35, Fres, Zrs and Rp correlated better with COPD. In particular, X5, X25 and Fres have been found to be significantly correlated with COPD. And these IOS parameters of sensitivity and specificity are good for COPD. For asthma, there was no significant difference in X5, X25 and Fres. But R5, X35 and Zrs had excellent correlations in asthma with high sensitivity and specificity. These parameters could be predicted COPD and asthma, respectively.

The results were an initial exploration of IOS parameters differences in resistance and reactance in patients with asthma compared with patients with COPD. We observed that peripheral airway resistance and airway elastic resistance increased in patients with COPD but not in patients with asthma. The measurement of IOS parameters showed that total airway resistance and viscous resistance were significantly elevated in asthma. The differences between the two diseases are consistent with the cellular and molecular features of airway inflammation and the degree of reversibility of airway flow limitation.

In conclusion, IOS parameters, X5, X25 and Fres may be useful for predictions and evaluations for COPD. And R5, X35 and Zrs may be as diagnostic markers in patients for asthma. Thus, IOS combined BDT could be useful diagnostic and differential diagnosis between asthma and COPD. In particularly, it suits for old people because IOS requires little patient cooperation and noninvasive and quick method.

Disclosure of conflict of interest

None.

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