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Original Article

Accuracy of Impulse Oscillometry in Airway Dysfunction

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Abstract

Background: The purpose of this study was to calculate and compare the specificity and sensitivity of impulse oscillometry (IOS) as a new technique in the detection of airways dysfunction by means of a simple pulmonary function test in chemical warfare injured cases suffering from respiratory diseases.

Methods: The study was performed prospectively in 100 patients, who complained of dyspnea as a result of sulfur mustard gas exposure in the Iran-Iraq war, between 1981 and 1988. Following a physical examination, IOS and spirometery were performed for all the patients. Then, the specificity and sensitivity of IOS parameters were calculated and compared with those of spirometery.

Results: With a routine cut-off point, R at 5Hz and R at 20Hz have a sensitivity and specificity of 48.9%, 70.4% and 40.0% and 85.2%, respectively. With a normal cut-off point of R at5Hz=<240 or R at20Hz=<180 or x at5Hz=>-0.20 kpal/l/s, there is a 100% specificity (PPV=100%).

Conclusion: While IOS is a new, cooperation independent technique and specific in the detection of airways dysfunction, it is less sensitive than spirometery in spotting small airways obstructions. IOS is a good diagnostic method in the detection of pulmonary involvements in uncooperative patients.
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Keywords ● Oscillometry ● spirometery ● mustard gas ● chemical warfare ● bronchiolitis

Introduction

The most important late complication of mustard gas is pulmonary involvement, which leads to a great number of difficulties for chemically injured patients. Bronchiolitis, chronic bronchitis and lung fibrosis have been reported as the most common pulmonary complications among mustard gas exposed victims.[1,2] Recent studies have reported small air ways diseases and, in particular, bronchiolitis as the main pulmonary complication in such patients.[3-6] Since bronchiolitis is a disease of the peripheral bronchioles, early detection (i.e., detection before a decline in forced expiratory volume in first sec [FEV 1]) requires a test sensitive enough to perceive early abnormalities of small airways. Several studies have demonstrated that spirometery is one of the best diagnostic methods for the detection of small air ways

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diseases. A forced expiratory flow of between 25% and 75% of FVC [forced vital capacity] has already been shown to become abnormal before a decline in FEV 1.[7,8] However, correct evaluation of the lung function by spirometery is highly dependent on the patient's cooperation.[9-11] Some studies have shown that the impairment of conductance and increase of resistance occur before a decrease in FEV1%.[7] Since BOS is a disease of the peripheral bronchioles, early detection (ie, detection before a decline in FEV1) would require a test sensitive to abnormalities of the mall airways. The forced expiratory flow between 25% and 75% of FVC (FEF25-75) and the single-breath nitrogen washout test (both tests of small airway dysfunction) have already been shown to become abnormal before a decline in FEV1.[12,13,7]

Impulse oscillometry has been reported as a simple non-invasive technique, which is useful in the measurement of the mechanical impedance of the respiratory system for the assessment of airflow obstruction.[14-17] Impulse oscillometry system (IOS) does not require active cooperation of the patient and has become commercially available. When compared with spirometery, the efficacy of this method has already been proved in children and also non-cooperative patients.[18-20] Nevertheless, there are few studies on impulse oscillometry in adults, and they are almost always based upon provocation tests.[21,22]

This study, however, was aimed at assessing IOS and spirometery in all ranges of pulmonary functions (normal to severe involvements) in chemical warfare injured subjects suffering from small airways dysfunction, without making use of any provocation tests. We calculated the specificity and sensitivity of impulse oscillometry in comparison to spirometery, as a gold standard, in the detection of small airways diseases of such patients.

Material and methods

Subjects

All the patients were non-smokers with respiratory complaints as a result of mustard gas exposure during the Iran -Iraq war, between 1981 and 1988.

Design

The study was performed prospectively in 100 patients suffering from dyspnea following exposure to mustard gas. The patients were evaluated in the respiratory clinic of Baqiyatallah Hospital in light of their respiratory symptoms between May 2003 and February 2004. All the patients received spirometery and impulse oscillometry by an expert technician under the supervision of a pulmonologist.

Spirometery was performed using pneumotachometer system "Sensormedix-version 4" should be changed to "SensorMedics, Yorba Linda, CA". The best MEFV curve, according to the ATS (American Thoracic Association) criteria, from at least 3 trials was selected. The patients who were able to reach the ATS criteria of acceptability and reproducibility were included into group 1, and the rest, not capable of meeting the ATS criteria, were categorized as group 2.

The impedance of the total respiratory system was measured using a commercially available oscillometry system (Masterlab-IOS, Erich Jaeger, Germany). During tidal breathing, through a mouthpiece on a Y-piece, an impulse generator produced brief pressure pulses at intervals of 0.2 sec. The power spectrum of the pulse was constant from 0 to 5 Hz in a range up to 40Hz. These pressure fluctuations were superimposed on the spontaneous breathing pattern and were measured at the mouth by means of a differential pressure transducer with a total resistance below 50 Pa/l/sec and a pressure range of ± 1 kPa. The digitized pressure and flow signals were sampled at a rate of 200 Hz and were fed into a fast Fourier transformation, which transformed the complex pulse signals into their elementary sinusoidal components. The spectral ratio of the amplitude of the pressure wave signal to the resulting flow signal constituted the impedance (Z) of the total respiratory system, from which the total resistance (R) and reactance (X) of the respiratory system were calculated. In this study, mean R at 5Hz(nl≤150%);R at 20Hz(nl≤150%);x at 5Hz(nl≥-0.24 kpal/l/s); z at 5Hz,F res; R central and R peripheral were calculated over a measurement period of 30 sec. During the IOS measurement, the patients were seated upright, with their head resting against the back of the chair. They were instructed to breath quietly through a mouthpiece. To reduce loss of energy in the upper airways, their cheeks and chin were supported by the hands of the technician, who was standing behind the patient.

The tests having been performed, spirometery and IOS data were compared. As it is shown in table 1 the last revised criteria for the categorization of BOS [bronchiolitis oblitrans syndrome] were used for the classification of PFT data.[23]

The patients were divided into three groups according to the results of spirometery: normal, small air ways diseases (FEF25-75 %< 75%) and obstructive diseases.[7,12,13] The study was performed in accordance with declaration of Helsinki and was approved by our university ethic committee.

Results are shown as mean (SD) and frequencies where indicated. ANOVA test was

Table 1: Original and proposed classifications of BOS

Original classifications		Current propositions	
BOS 0	FEV1% 80% or more of baseline	BOS 0	FEV1% > 90% of baseline And FEF25–75 >= 75% of baseline
		BOS 0-p	FEV1% 81% to 90% of baseline And/or FEF25–75 < 75% of baseline
BOS 1	FEV1% 66% to 80% of baseline	BOS 1	FEV1% 66% to 80% of baseline
BOS 2	FEV1% 51% to 65% of baseline	BOS 2	FEV1% 51% to 65% of baseline
BOS 3	FEV1% 50% or less of baseline	BOS 3	FEV1% 50% or less of baseline

BOS, bronchiolitis obliterans syndrome; FEF25–75, mid-expiratory flow rate; FEV1%, forced expiratory volume in 1 second.

applied to compare IOS parameters between groups (normal, small air ways diseases and obstructive diseases). Diagnostic values including sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated. All data were analyzed by SPSS12.

Results

Ninety-eight out of the100 patients were male with a mean age of 41 years (30-70 years, SD=7.3). All of them were chemically injured cases during the Iran- Iraq war, between 1981 and 1988. They had a mean exposure time of 16.9 years (14 to 21 years) and complained of respiratory symptoms (coughs, dyspnea, sputum, hemoptesis, etc ...). A description of the studied population is shown in table 2. Table 3 demonstrates the details of spirometry and ISO parameters of the patients.

Table 2: frequencies(%) of clinical manifestation and lung examination of patients

Respiratory symptoms	
Coughs	91%
Sputum	73%
Dyspnea	91%
Hemoptesis	39%
Respiratory signs	54%

We divided the patients in terms of cooperation into 2 groups: 74% of them cooperated fully in spirometery, which yielded the following results: 28 patients (38.4%) had normal spirometery, 23 subjects (31.0%) suffered from small air ways diseases and the remaining 23 individuals (31.0%) exhibited significant obstructive patterns.

The IOS parameters for each of these groups were compared separately (table 4). The sensitivity and specificity of the IOS parameters were calculated (R at5Hz, Rat 20Hz,X at5Hz,F res, R central and R peripheral), and the data of the cooperative and non-cooperative groups were compared. With normal cut-off point, R at 5Hz, R at 20Hz and X at 5Hz had a sensitivity of 48.9%, 40.0% and 28%, respectively. The corresponding specificities were 70.4%, 85.2% and 100%, respectively. With a normal cut-off point of R at 5Hz≤240 or R at 20Hz≤180 or x a t5Hz≥-0.20 kpal/l/s, there was a 100% specificity (PPV=100%) (table 5).

In the non-cooperative patients(group 2), R at 5Hz, R at 20Hz and x at 5 Hz were abnormal in 20%, 16% and 24% of the cases, respectively.

Discussion

Many studies have shown the diagnostic values of spirometery as a sensitive method for the detection of air ways obstruction. FEV1% is shown to be a widely accepted and well standardized parameter of airflow obstruction.[24] However, IOS may have some benefits. Independence from the patient's cooperation, short duration of the procedure and capability of detecting proximal and distal air ways obstructions make IOS a reliable method for lung evaluation, especially in children and non-cooperative patients.[16,25]

Wang and colleagues,[26] investigated the diagnostic significance of total respiratory impedance

Table 3: spirometery and IOS parameters

	N	Minimum	Maximum	Mean	Std. Deviation
VC* in max	96	37.0	122.0	81.3	17.1
FEV1%**	98	20.0	121.0	78.6	21.2
FEV1%/VC max	97	41.0	130.0	82.6	16.4
PEF%[¥]	99	24.4	197.0	74.7	27.4
co operation	100	1.0	2.0	1.3	0.44
R at 5Hz%	96	57.5	503.1	161.1	83.9
R at 20Hz%	96	48.7	310.0	125.6	55.7
x at 5Hz	96	-0.95	0.30	-0.18	0.19
z at 5Hz%	96	33.0	580.1	170.8	100.4
Fres[§]	96	4.0	44.2	20.4	6.1
R central	96	0.03	0.48	0.22	0.10
R peripheral	96	0.10	1.95	0.37	0.34

*Vital Capacity, **Forced Expiratory Volume in first second, ¥ Peak Expiratory Flow §Resonant frequency

Table 4: Comparison of IOS and each group of spirometery

parameters	Groups	Mean(SD)	P-Value
	normal	128.0(44.7)	
R at 5Hz%	small air way	155.5(69.0)	0.001
	obstructive	205.0(110.5)	
	Normal	104.5(34.6)	
R at 20Hz%	small air way	127.5(57.9)	0.005
	obstructive	148.2(65.1)	
	normal	-0.12(0.03)	
x at 5Hz	small air way	-0.13(0.10)	0.0001
	Obstructive	-0.28(0.29)	
	normal	129.2(43.2)	
z at 5Hz%	small air way	163.5(67.2)	0.0001
	Obstructive	225.9(142.5)	
	Normal	18.4(4.0)	
Fres* (Hz)	small air way	19.4(5.2)	0.001
	Obstructive	23.6(7.7)	
	normal	0.19(08)	
R central	small air way	0.24(0.11)	0.03
	obstructive	0.24(0.11)	
	normal	0.24(0.08)	
R peripheral	small air way	0.30(0.13)	0.0001
	obstructive	0.58(0.52)	

*Resonant frequency

Table 5: sensitivity and specificity of IOS parameters

	Cut off point of Abnormal test	Sensitivity	Specificity	PPV*	NPV**
R at 5 Hz%	≥150	48.9	70.4	73.3	45.2
	≥ 240	22.2	100.0	100.0	44.4
R at 20 Hz%	≥ 150	40.0	85.2	81.8	46.0
	≥ 182	15.6	100.0	100.0	42.4
X at 5 Hz	≤ -.20	28.9	100.0	100.0	46.7
Z at 5 Hz%	≥ 225	33.3	100.0	100.0	48.3
Fres ***(Hz)	≥0.29	17.8	100.0	100.0	42.2

*Positive Predictive Value, ** Negative Predictive Value,*** Resonant frequency,

for chronic obstructive lung disease compared to parameter values of routine pulmonary function in 57 patients with chronic obstructive pulmonary disease (COPD). The sensitivity of resonant frequency, R5 and X5 for diagnosing COPD were 94.74%, 59.65% and 54.38%, respectively. Their specificity was 86.66%, 96.66% and 90%, respectively. Resonant frequency was the most sensitive index in the parameters measured by IOS for the diagnosis of COPD. They concluded that this technique could, therefore, be applied in COPD patients with acute attack for dynamic examinations.[26]

In another study, Bassiri and colleagues,[7] compared the potential utility of specific airways conductance (sGaw) in detecting small airways dysfunction in post lung-transplant bronchiolitis obliterans syndrome (BOS), which was used as a model of small airways dysfunction. Having reviewed the spirometery and sGaw measurements in patients undergoing heart-lung or bilateral lung transplantation, they concluded that sGaw tended to decrease before FEV 1 in BOS, and that the trend in sGaw was similar to that in FEF 25-75%.[7]

In contrast to Bassiri et al, our study showed that spirometry was preferable to IOS in the detection of small air ways dysfunction.

There are a number of studies on the utility of IOS in children. Vink and colleagues,[25] evaluated the sensitivity and specificity of IOS parameters to quantify changes in airflow obstruction in comparison with FEV1% and PEF% measurements in 19 children with asthma before, during and after methacholine challenge and subsequent bronchodilation. They concluded that IOS parameters could be easily used as an indirect measure of airflow obstruction. In individual subjects, R values measured at 5 Hz showed to be superior to PEF% measurements in the detection of a 15% fall in FEV1%.[25]

It is also of note that here has been another study demonstrating that airway resistance of cystic fibrosis patients can be adequately estimated by forced impulse oscillometry.[27]

But, Oostveen and colleagues described the basic principle of the technique and gave guidelines for the application and interpretation of FOT as a routine lung function test in the clinical setting. They concluded that forced oscillation technique has been shown to be as sensitive as spirometery in detecting impairment of lung function due to occupational hazards.[28]

Although previous reports have noted that IOS is one of the favorable diagnostic methods for the evaluation of airways obstruction and that it is recommended as a valuable technique for the evaluation of the lung function, the results of the present study point out a lower sensitivity of IOS in comparison to spirometery in detecting small air ways obstruction in non-smoking mustard induced COPD cases. In this study, patients with a broad range of pulmonary involvements (normal to severe obstructions) were evaluated. In the 23 patients with only small airways obstruction in the spirometery measurements (FEF25-75 %< 75%), ISO had moderate sensitivity and good specificity in the detection of small airways dysfunction. R at 5Hz and R at 20Hz as a resistance model, and x at5Hz as a reactance model have good specificity, but even in these cases the sensitivity of spirometery is higher than that of IOS. Future studies on diagnostic values of IOS applying other standard tests as single-breath nitrogen washout may provide more evidences.

Conclusion

While IOS is a new, cooperation-independent technique and specific in the detection of airways dysfunction, it is less sensitive than spirometery for detection of small airways obstructions in non-smokers with respiratory complaints. IOS is a good diagnostic method in the detection of pulmonary involvements in uncooperative patients. Therefore, spirometery is the best diagnostic method for the detection of airways dysfunction, whereas IOS is a valuable method only when we have non-cooperative patients for spirometery.

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