Accuracy of Impulse Oscillometry in Airway Dysfunction

M. Ghanei, F. Darvishzadeh, F. Alaeddini, I. Adibi, J. Aslani

Baqiyatallah University of Medical Sciences,
Research Center of Chemical Injuries,
Tehran, Iran.

Correspondence:
Mostafa Ghanei MD,
Baqiyatallah University of Medical Sciences,
Research Center of Chemical Injuries,
P.O. Box: 19945-546
Tehran, Iran.
Tel: +98 21 8053770
Fax: +98 21 8040106
Email: m.ghanei@bmsu.ac.ir

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 spirometry were performed for all the patients. Then, the specificity and sensitivity of IOS parameters were calculated and compared with those of spirometry.

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 spirometry in spotting small airways obstructions. IOS is a good diagnostic method in the detection of pulmonary involvements in uncooperative patients.

Keywords • Oscillometry • spirometry • 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 airways 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 spirometry is one of the best diagnostic methods for the detection of small air ways.
diseases. A forced expiratory flow of between 25% and 75% of FVC [forced vital capacity] has already been shown to become abnormal before a decrease in FEV1. However, correct evaluation of the lung function by spirometry is highly dependent on the patient’s cooperation. Some studies have shown that the impairment of conductance and increase of resistance occur before a decrease in FEV1%. 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 small 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.

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. Impulse oscillometry system (IOS) does not require active cooperation of the patient and has become commercially available. When compared with spirometry, the efficacy of this method has already been assessed in children and non-cooperative patients. Nevertheless, there are few studies on impulse oscillometry in adults, and they are almost always based upon provocation tests.

This study, however, was aimed at assessing IOS and spirometry 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 spirometry, 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 spirometry and impulse oscillometry by an expert technician under the supervision of a pulmonologist.

Spirometry 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 40 Hz. 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 5 Hz (nl±150%); R at 20 Hz (nl±150%); X at 5 Hz (nl≥0.24 kpal/l/s); z at 5 Hz, Fr 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 breathe 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, spirometry and IOS data were compared. As it is shown in table 1 the last revised criteria for the categorization of BOS [bronchiolitis obliterans syndrome] were used for the classification of PFT data.

The patients were divided into three groups according to the results of spirometry: normal, small airway diseases (FEF25-75 %< 75%) and obstructive diseases. 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
Impulse oscillometry in airway dysfunction

Iran J Med Sci
December 2007; Vol 32 No 4 207

applied to compare IOS parameters between groups (normal, small airways 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 the 100 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 IOS 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 spirometry, which yielded the following results: 28 patients (38.4%) had normal spirometry, 23 subjects (31.0%) suffered from small airways 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 at 5Hz, R at 20Hz, X at 5Hz, Fres, 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 at 5Hz≥-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 spirometry as a sensitive method for the detection of airways obstruction. FEV1% is shown to be a widely accepted and well standardized parameter of airflow obstruction. However, IOS may have some benefits. Independence from the patient’s cooperation, short duration of the procedure and capability of detecting proximal and distal airways obstructions make IOS a reliable method for lung evaluation, especially in children and non-cooperative patients.

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

Table 3: spirometry and IOS parameters

<table>
<thead>
<tr>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC* in max</td>
<td>96</td>
<td>37.0</td>
<td>122.0</td>
<td>81.3</td>
</tr>
<tr>
<td>FEV1%**</td>
<td>98</td>
<td>20.0</td>
<td>121.0</td>
<td>78.6</td>
</tr>
<tr>
<td>FEV1%/VC max</td>
<td>97</td>
<td>41.0</td>
<td>130.0</td>
<td>82.6</td>
</tr>
<tr>
<td>PEF%§</td>
<td>99</td>
<td>24.4</td>
<td>197.0</td>
<td>74.7</td>
</tr>
<tr>
<td>co operation</td>
<td>100</td>
<td>1.0</td>
<td>2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>R at 5Hz%</td>
<td>96</td>
<td>57.5</td>
<td>503.1</td>
<td>161.1</td>
</tr>
<tr>
<td>R at 20Hz%</td>
<td>96</td>
<td>48.7</td>
<td>310.0</td>
<td>125.6</td>
</tr>
<tr>
<td>x at 5Hz</td>
<td>96</td>
<td>-0.95</td>
<td>0.30</td>
<td>-0.18</td>
</tr>
<tr>
<td>z at 5Hz%</td>
<td>96</td>
<td>33.0</td>
<td>580.1</td>
<td>170.8</td>
</tr>
<tr>
<td>Pres</td>
<td>96</td>
<td>4.0</td>
<td>44.2</td>
<td>20.4</td>
</tr>
<tr>
<td>R central</td>
<td>96</td>
<td>0.03</td>
<td>0.48</td>
<td>0.22</td>
</tr>
<tr>
<td>R peripheral</td>
<td>96</td>
<td>0.10</td>
<td>1.95</td>
<td>0.37</td>
</tr>
</tbody>
</table>

*Vital Capacity, **Forced Expiratory Volume in first second, §Peak Expiratory Flow §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.

In another study, Bassiri and colleagues, 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 spirometry and sGaw measurements in patients undergoing heart-lung or bilateral lung transplantation, they concluded that sGaw tended to decrease before FEV1 in BOS, and that the trend in sGaw was similar to that in FEF 25-75%.

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

There are a number of studies on the utility of IOS in children. Vink and colleagues, 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%.

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.

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 spirometry in detecting small airways 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 spirometry 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 spirometry 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 spirometry 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, spirometry 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 spirometry.

Acknowledgement

The authors aim to thank Prof. H. J. Smith for his useful comments on the manuscript.

References

2 Emad A, Rezaian GR. The diversity of the effects of sulfur mustard gas inhalation on respiratory system 10 years after a single heavy exposure: analysis of 197 cases. Chest 1997; 112: 734-8.
17 Hadjikoumi I, Hassan A, Milner AD. Exhaled nitric oxide measurements in childhood


