Impulse oscillometry usefulness in small-airway dysfunction in asthmatics and its utility in asthma control
Ragia S. Sharshar

**Background** Small-airway affection and its relation to clinical status in asthmatic patients became an increasing interest during the last decade. Spirometry is a basic diagnostic tool for measuring pulmonary function in asthmatics but not fully illustrative especially in assessing small airways. Impulse oscillometry (IOS) can be considered a complementary and sometimes alternative technique to spirometry because it is used during quiet breathing and so gives more data about small-airways affection in asthmatic patients.

**Aim** To evaluate IOS usefulness in the detection of small-airways disease in asthma and its correlation to the level of disease control.

**Patients and methods** The study was conducted on 44 asthmatic patients who were classified into two groups: controlled asthma and uncontrolled asthma by asthma control test questionnaire (ACT score). Spirometry and IOS were performed on all patients.

**Results** Small-airway IOS values (R5–20, X5, and AX) were found to be statistically significant between two groups. Moreover, they strongly correlated significantly with clinical symptoms, assessed by ACT. There was high sensitivity and specificity of (R5–20) 80 and 82%, (X5) 80 and 86%, and (AX) 86 and 89%, while for spirometric data only forced expiratory flow (FEF_{25–75}) showed a statistically significant difference between the two groups, and not FEV_{1} and there was poor correlation between ACT and FEF_{25–75}.

**Conclusion** IOS provides an easy and rapid tool to diagnose and assess small-airways disease in adult, asthmatic patients Egypt J Bronchol 2019 13:452–458

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**Keywords:** asthma, impulse oscillometry, small-airway dysfunction

**Patients and methods** This prospective, cross-sectional study was done on 44 asthmatic patients, recruited from the Chest Department, Tanta University, from May 2016 to February 2017 those who fulfilled the ethics committee considerations. Exclusion criteria were smokers and ex-smokers, hospitalization in the last 1 month, respiratory tract infection, and concomitant chest diseases.

After a written, informed consent has been taken, detailed medical history, thorough clinical examination and chest radiograph, spirometry (forced expiratory volume at first second (FEV_{1})/forced vital capacity (FVC), FEV_{1}%, forced expiratory flow (FEF_{25–75}%) and IOS (R5, R5–20, X5, AX) measurements were done on all patients.

All patients were diagnosed with asthma based on medical history, physical examination, and GINA guidelines [10].

The study patients were classified into two groups: controlled asthma and uncontrolled asthma according to the Global Initiative for Asthma (GINA) 2017 guidelines [10].

**Introduction**
Asthma is a chronic inflammatory disorder that affects the entire tracheobronchial tree, including not only central but also peripheral membranous bronchioles that represents small-airways affection. Remodelling of small-airways affecting both clinical aspect with poor asthma control, more frequent exacerbations, as well as influence functional manifestations of asthma making airflow limitation irreversible [1–3].

Functional evaluation of small-airways is still a matter of challenge, as the classical use of spirometry parameters is still not fully descriptive [4].

Impulse oscillometry (IOS), a technique first described 60 years ago, was recently used successfully to evaluate lung function in healthy individuals and asthmatics [5,6].

IOS can measure both proximal and peripheral resistance in both adults and pediatric asthmatics. The main advantage of IOS is it is simple, noninvasive, sensitive and moreover does not need a forced technique that affects the bronchial tone [7–9].
to the asthma control test, which is a five-point questionnaire applied to evaluate asthma control clinically. Each of the five questions of asthma control test (ACT) was explained to patients before completion of questionnaire, patients were considered having controlled asthma if the ACT score is more than 20 points and uncontrolled asthma if the ACT score is 19 or less (Fig. 1) [11,12].

IOS maneuver was performed using Master Lab-IOS Unit (Master Screen IOS 2001, version 4.5; Erich Jaeger GmbH, Hochberg, Germany), following standard recommendations [9].

The IOS device consists of measuring head, resistor, a pneumotachograph, pressure and flow transducers, and a computer. The system was calibrated for volume before data collection using a 3-L syringe. The patient was asked to breathe normally (tidal breathing) while seated in a relaxed sitting position, the head held slightly extended, with lips making a tight seal and tongue below a well-fitted mouthpiece. To avoid the compliance of cheeks, place firmly the patient’s hands directly over them, with a nasal clip placed to occlude the nares. Impulses were applied for 30–45 s, IOS data were reviewed, with rejecting segments affected by airflow leaks or swallowing artifacts. IOS used to assess respiratory resistance at 5 Hz ($R_5$) indicates total resistance. Respiratory reactance at 5 Hz ($X_5$) detects peripheral elastic recoil of airways. Reactance area ($Ax$) is an integration index of reactance measure from $X_5$ to $F_{res}$ [13–15].

R5–20 is defined by the difference between low-frequency total resistance ($R_5$) and high-frequency central resistance ($R_{20}$), and hence derives peripheral airway resistance. So peripheral airway obstruction is reflected by elevated R5–20 because pressure waves signal passes into the distal lung, that is, $R_5$, encounters more resistance than higher frequency more proximal $R_{20}$ impulse. Peripheral airway obstruction leads to loss of elastic recoil expressed as less $X_5$ and more $Ax$. $R_5$–20 is considered abnormal if higher than 0.03 kPa/l; $X_5$ is considered normal if it equals $X_5$ predicted 0.15 kPa/l; $Ax$ was considered normal if it equals 0.33 kPa/l [15–17].

**Statistical analysis**

Statistical analysis was done using SPSS (IBM Corp. Armonk, New York, USA) version (20). Continuous...
data were expressed as mean±SD and categorical variables as percentages. Pearson’s linear correlation coefficient was used for the correlation between ACT scores and lung function. *P value of less than 0.05 was considered significant.

**Results**

A total of 44 asthmatics were included, their mean age was 43.3±12.4 years with the percentage of women to men being 72.7–27.3%. Basic demographic data of patients in both groups are illustrated in Table 1. As for ACT, the mean value was 20.88±2.191, 29 out of 44 (65.9%) cases had uncontrolled asthma while 15 out of 44 (34.1%) was controlled (Table 2).

Spirometric parameters showed that the mean value of FEV₁% was 81.27±5.79 and 78.48±4.64 in groups I and II, while FEF₂₅₋₇₅% was 62.93±4.03 and 44.17±3.55 in groups I and II, respectively. A statistically significant difference between FEF₂₅₋₇₅% in two groups was detected, and not FEV₁%. On correlation with ACT, there was poor correlation between ACT and FEF₂₅₋₇₅%, while no correlation was detected between ACT and FEV₁ (Tables 1 and 3).

Small-airway IOS parameters were statistically significant between controlled and uncontrolled asthma (*P<0.05) Moreover, small-airways evaluated by IOS indices, R₅₋₂₀, X₅, and AX values strongly correlated significantly with clinical symptoms, assessed by the ACT (Tables 1 and 3 and Figs 2–4). There was high sensitivity and specificity of (R₅₋₂₀) 80 and 82%, (X₅) 80 and 86%, and (AX) 86 and 89% (Table 4).

**Discussion**

Poor evaluation of asthma control is a crucial element of suboptimal asthma management, so the challenge now is to shift to a management approach based on the level of control [18].

Symptoms and lung function assessment considered the different domains of asthma that correlate poorly over time, so both clinical and functional assessment need to be monitored by physicians to evaluate asthma control [19].

Although no comprehensive tool exists to define asthma control sharply, many tools were used for this purpose, one of these was a five-item self-administered asthma control test [11,12].

In our study according to the ACT score, 65.9% patients had uncontrolled asthma while 34.1% patients had controlled asthma. Similar findings were reported by many previous authors, some reported 37% well-controlled asthma and another hospital-based study found only 28% well-controlled asthma. This was in contrast to other studies that showed controlled asthma was from 47% up to 80% in the studied patients [12,20–22].

Regarding spirometric values, we analyzed FEF₂₅₋₇₅%, the most commonly used indicator of small-airways affection and FEV₁%, where we found that FEF₂₅₋₇₅% was statistically significant between the two groups

**Table 1 Level of control in the study groups, based on asthma control test**

<table>
<thead>
<tr>
<th>Level of control</th>
<th>Controlled asthma (group I)</th>
<th>Uncontrolled asthma (group II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>15/44</td>
<td>29/44</td>
</tr>
<tr>
<td>Percentage</td>
<td>34.1</td>
<td>65.9</td>
</tr>
</tbody>
</table>

**Table 2 Basic demographic data of patients in both groups**

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Controlled asthma (group I)</th>
<th>Uncontrolled asthma (group II)</th>
<th>t-Test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>15/44</td>
<td>29/44</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Baseline spirometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEV₁, %predicted</td>
<td>81.27±5.79</td>
<td>78.48±4.64</td>
<td>3.001</td>
<td>0.091</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅, %predicted</td>
<td>62.93±4.03</td>
<td>44.17±3.55</td>
<td>252.38</td>
<td>0.001*</td>
</tr>
<tr>
<td>Baseline IOS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R₅₋₂₀</td>
<td>0.68±0.31</td>
<td>1.68±0.29</td>
<td>156.99</td>
<td>0.001*</td>
</tr>
<tr>
<td>X₅</td>
<td>−0.85±0.19</td>
<td>−1.40±0.21</td>
<td>70.98</td>
<td>0.001*</td>
</tr>
<tr>
<td>AX</td>
<td>4.40±2.67</td>
<td>13.45±2.56</td>
<td>119.95</td>
<td>0.001*</td>
</tr>
<tr>
<td>ACT</td>
<td>22.27±0.80</td>
<td>15.48±1.40</td>
<td>297.77</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

FEV₁, asthma control test; FEF, forced expiratory flow; IOS, impulse oscillometry. *P ≤0.05, statistically significant.

**Table 3 Correlation between spirometric, impulse oscillometry parameters, asthma control test in both groups**

<table>
<thead>
<tr>
<th>Asthma control test</th>
<th>Controlled asthma</th>
<th>Uncontrolled asthma</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>P</td>
<td>r</td>
</tr>
<tr>
<td>FEV₁%</td>
<td>−0.147</td>
<td>0.214</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅%</td>
<td>0.297</td>
<td>0.107</td>
</tr>
<tr>
<td>R₅₋₂₀</td>
<td>−0.814</td>
<td>0.001*</td>
</tr>
<tr>
<td>X₅</td>
<td>0.828</td>
<td>0.001*</td>
</tr>
<tr>
<td>AX</td>
<td>−0.895</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

FEF, forced expiratory flow. *P ≤0.05, statistically significant.
Figure 2

Correlation between R5–20 and asthma control test in both groups.

Figure 3

Correlation between X5 and asthma control test in both groups.
with no significant correlation between ACT and FEV1%. These results were highlighted by several studies, indicated only weak correlations between clinical symptoms, and airflow limitation evaluated by FEV1 [23,24].

Other previous studies by Johnbull et al. [20] showed that the correlation between the asthma control test and pulmonary function tests was not significant. This was also in accordance with the findings reported by Green et al. [25], Reznik et al. [26], and Osborne et al. [27].

Unlike our study, Mendoza et al. [12], found a correlation between FEV1 and ACT. This significant correlation probably was due to a larger study and it was a prospective cohort study. Moreover, Chalise reported positive correlations between FEV1 and ACT test [12,28].

The poor correlation between ACT and FEF25–75% may be partly due to that asthma symptoms lack specificity and also due to variations in magnitude and time of response to therapy [29].

This poor correlation can be explained first by the presence of marked measurement variability over age range, second by the fact that forced expiratory maneuver tends to exaggerate volume-dependent small-airway closure, which means FEF25–75 degree of variability is affected by effort-dependent expiration from total lung capacity to residual volume. So FEF25–75% is dependent on FVC, and if not adjusted it gives poor reproducibility; moreover, it is frequently normal if the FEV1/FVC ratio is more than 75%; lastly, there is poor correlation with other markers of small-airways such as FVC and residual volume.
(RV)/total lung capacity (TLC) due to the alteration of FVC with air trapping; therefore, there is much doubt about the ability of FEF_{25–75}\% to clarify small-airways affection [30–32].

As for IOS parameters, we found that small-airway IOS parameters were statistically significant between controlled and uncontrolled asthma (P<0.05) with high sensitivity and specificity. Also, these values correlated significantly with clinical symptoms, assessed by ACT. Many previous studies have shown obvious relationship between small-airway assessed by IOS and uncontrolled asthma [33].

Takeda et al. [2] found that IOS correlated better with clinical symptoms and disease control in contrast to spirometry FEV_{1} that did not contribute to clinical status or dyspnea. Another study by Allerini et al. [14] showed that asthmatics with increased peripheral resistance had poorly controlled asthma. Moreover, they did not differ from patients with normal values of peripheral resistance measured by spirometric FEV_{1} and FEV_{1}/FVC.

### References
