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# Comparison of changes in lung function measured by plethymography and IOS after bronchoprovocation

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**Summary**
*Aim:* Lung function tests are essential for the diagnosis and management of bronchial asthma. Impulse oscillation (IOS) system is an alternative way to measure lung mechanics for some patients. We investigated the relative sensitivities of IOS, body plethysmography and spirometry in detecting allergen- and methacholine-induced bronchoconstriction.
*Method:* Twenty-two subjects had single allergen inhalation and 8 subjects had 3 methacholine challenges. The tests were stopped when $FEV_1$ fell by 20%. Lung function was measured using IOS (R5, R20, R5-R20, X5, AX, fres), plethysmography (sRaw, sGaw, FRC, lung volumes) and spirometry ($FEV_1$, FVC, PEF, $FEF_{50\%}$) during inhalation challenges, and expressed as percent change from pre-challenge baseline.
*Results:* All subjects were non-smoking adults with mild allergic asthma. Following allergen challenges, the most sensitive IOS index was R5–R20 and the most sensitive plethysmography and spirometry measurements were sRaw, sGaw and $FEF_{50\%}$. Following methacholine challenge the most sensitive IOS index was AX, the most sensitive plethysmography measurement was sRaw. Overall, IOS (R5–R20, AX, X5 Hz) proved to be more sensitive than plethysmography and spirometry measurements following allergen-induced and methacholine-induced bronchoconstriction.
*Conclusion:* Our result shows that IOS is more sensitive than other lung function tests following allergen and methacholine challenge. In addition, IOS can act as an alternative measurement technique of airway resistance and obstruction in patients where manoeuvres involved in plethysmography and spirometry prove difficult to perform.


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## Introduction

Bronchial asthma is most commonly evaluated using spirometric and plethysmographic measurements made at baseline, following bronchodilators or during bronchial provocation testing. For some patients such as children, institutionalized and frail elderly patients and those with difficulty performing forced respiratory manoeuvres, alternative tests have been suggested.[1–3]

There is a poor correlation between asthma, degree of airflow obstruction and $FEV_1$,[4,5] which is partly related to airway hyper-responsiveness (AHR), hyperinflation and fluctuation of $FEV_1$. This suggests the need for a more sensitive test, such as impulse oscillometry, which may be used for better evaluation of lung mechanics particularly during methacholine-induced AHR.[2,6–10]

The forced oscillation technique (FOT) was introduced by Dubois and colleagues over 50 years ago as an alternative way to measure the mechanics of the respiratory system to the traditional simultaneous measurements of pressure, flow and volume at normal breathing frequencies.[11]

The Jaeger impulse oscillation system (IOS, Erich Jaeger, Hoechberg, Germany) was introduced as a user-friendly commercial version of the FOT. The utility of IOS arises because it is simple, rapid, non invasive, does not require forced manoeuvres that could influence bronchial tone, and does not require confined spaces.[12,13] IOS measures pulmonary impedance (Xrs) over a range of frequencies (5–35 Hz). Lower frequencies (5 Hz) have a slower cycle time and shorter wavelength, and reach the periphery of the lungs. Pulmonary resistance (R) and reactance (X), which is a composite index for airway elasticity and inertia can be measured at lower frequencies (R5 and X5 Hz) to give information about the entire airway. Frequencies propagate from central to peripheral airways, therefore, R5 and X5 increase when there is central or peripheral airway obstruction. Higher frequencies (20 Hz) have a faster cycle time and longer wavelength. These signals only penetrate and give information about the proximal and larger airways, therefore increasing resistance at R20 principally indicates central airflow obstruction. Disease confined to distal airways, however, will increase resistance at the R5 more than at the R20, as the latter constitutes only a small percentage of the total resistance. This is measured as a differential change (R5–R20). The area under curve of reactance (AX) between 5 Hz and resonant frequency (fres) represents a composite index for reactance.

Previous studies showed that IOS measurements are reproducible and provide sensitive indices compared to $FEV_1$.[1,14–16] It has been shown to be very sensitive in assessment of airway hyper-responsiveness, airflow obstruction, bronchodilator reversibility, in patients with asthma and COPD.[17,18] Vink and coworkers demonstrated that the sensitivity of R and X to airway obstruction was best at 5–15 Hz, and the rise in resistance preceded the fall in $FEV_1$, suggesting an increased sensitivity of IOS.[1] This may provide a significantly lower threshold value for AHR, making methacholine challenge safer and faster. Other studies have supported these findings.[19] IOS has also been shown to correlate well with methacholine-induced symptoms of dyspnoea, wheeze and chest tightness, and closely associated with less dyspnoea scores in asthmatics.[14,15]

While a few studies in the past have compared forced oscillation technique with that of spirometry in subjects with asthma following allergen-induced bronchoconstriction[20–22] there have been no studies comparing the relative sensitivities of IOS, plethysmography and spirometry in adult asthmatic subjects following allergen-induced bronchoconstriction. We investigated the relative sensitivities of IOS (R5Hz, R20Hz, R5–R20, X5Hz, AX) to that of body plethysmography (sRaw, sGaw, FRC) and spirometry ($FEV_1$, PEF, $FEF_{50\%}$) in detecting bronchoconstriction following allergen inhalation and methacholine challenge.

## Methods

### Subjects

Twenty-two subjects were recruited for single allergen inhalation challenges and 8 subjects were recruited for methacholine challenges. The study was approved by the institutional Research Ethics Board, and all subjects provided signed informed consent. Subjects were non-smoking adults with mild allergic asthma as defined by methacholine $PC_{20} \leq 16$ mg/ml and $FEV_1 \geq 70\%$ predicted during a screening visit, and infrequent (<twice weekly) use of short-acting $\beta_2$-agonists. Subjects were excluded if they had lower respiratory tract infection, asthma exacerbation within 4 weeks or used inhaled or oral steroids within 4 weeks. Short-acting $\beta_2$-agonists were withheld 8 h before all visits and antihistamines were withheld 72 h before allergen challenges. Subject characteristics are shown in Tables 1 and 2.

### Study design

This observational study was conducted to determine the relative sensitivity of IOS, plethysmography and spirometry in detecting allergen- and methacholine-induced bronchoconstriction. Following each inhalation period, measurements of IOS, plethysmography and spirometry were obtained, in this order, to avoid the effect of forced manoeuvres of plethysmography and spirometry on bronchial tone during IOS.

### Impulse oscillometry

The impedance of the total respiratory system was measured using a MasterLab IOS system (Erich Jaeger Co, Wurtzburg, Germany). During tidal breathing for 30 s, an impulse generator produced brief pressure pulses (150 impulses) at intervals of 0.2 s and the pressure fluctuations were measured at the mouth. Subjects sat upright with, nose clip in place and hands supporting the cheeks. Mean resistance (R5, R20, R5–R20) Hz and reactance at 5 Hz (X5), reactance area (AX) and resonant frequency (fres) were calculated.