

Forced Oscillometry: A New Tool for Assessing Airway Function—Is It Ready for Prime Time?



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The forced oscillometry technique (FOT) is a relatively new modality for measuring airway function using physics quite distinct from traditional expiratory spirometry, or from body plethysmography. Dubois et al¹ were the first to describe physiologic concepts of FOT in 1956, and the procedures initially described have been adopted into modern protocols worldwide. FOT is typically performed in a seated patient breathing at tidal volume, with a nose clip in place and the cheeks firmly supported by the patient. A sound generator injects sound waves from approximately 5 to 30 Hz (or a low-frequency square wave from which multiple frequencies can be derived using advanced mathematics) into the airstream and respiratory tract of the patient. The higher frequencies (approximately 20 Hz) interrogate the large proximal airways to the mouth piece and the lower frequencies (approximately 5 Hz) reach both proximal and distal airways. Signal filtering separates pressure and flow variation during quiet inspiration and expiration. FOT does not require forced expiratory maneuvers. Consequently, it has found utility in the pediatric population and in adults too weak or otherwise unable to perform spirometry.² FOT may also be useful where spirometry is contraindicated, such as in patients who recently underwent surgery, or have recurrent pneumothoraces, or with spirometry-related bronchospasm.

FOT measures the respiratory system impedance (Z_{rs}) during spontaneous breathing; consequently, there are minimal lung volume changes that could artifactually alter the measurements (ie, bronchodilation after deep inspiration). Respiratory impedance is a complex value from which respiratory resistance (R_{rs}) and respiratory reactance (X_{rs}) can be extracted quantitatively. Parameters of FOT are different than those obtained with forced expiratory spirometry. Resistance (R) measured by FOT is physically and numerically similar to resistance measured in a

plethysmograph, but the frequency dependence of R , and the ability to disentangle resistance in larger and smaller airways, provides added clinical information. Reactance (X) is the sum of inertance and elastance, and has a relationship with pulmonary compliance and viscoelastic properties that is not fully defined, but is most commonly reported as reactance at 5 Hz (X_5). The resonant frequency (F_{res}) represents the frequency at which the elastance and inertance signals are equal and opposite at which the total reactance is zero. F_{res} is higher in children, falls with lung maturation, and is increased by pulmonary disease. The area of reactance (A_X) represents the total reactance (area under the curve) at all frequencies between 5 Hz and F_{res} . This single value integrates signals from all frequencies measured by FOT where the elastic properties of the lung (capacitance) dominate over inertance. Coherence is an index of the quality of the test, signified by coherence at 5 Hz > 0.8 and coherence at 20 Hz > 0.9 . An improper technique, swallowing, obstruction of airflow by the tongue, inadequate seal between the patient and mouth piece, and irregular breaths may adversely affect coherence. Respiratory system resistance (R_{rs}) is a measure of the airflow resistance of the airways. Resistance at 5 Hz (R_5) is representative of total airway resistance, whereas resistance at 20 Hz measures proximal airway resistance. Distal (small) airway resistance can be measured as the difference between R_5 and R_{20} .

Asthma and chronic obstructive pulmonary disease (COPD) are common pulmonary diseases characterized by airflow limitation affecting up to 10% of the population of the United States and are associated with high morbidity and mortality. COPD alone is responsible for 120,000 deaths per year in the United States and is the third-ranked cause of death in the United States. Given the broad impact that obstructive lung diseases have on the United States and worldwide, a better screening tool to diagnose, classify severity, measure response to bronchodilators, and detect early airway hyper-responsiveness would be instrumental. Early recognition of obstructive lung disease would allow practitioners to counsel patients on the avoidance of risk factors associated with disease progression, and help provide appropriate therapy.

In this issue of the *Journal of Allergy and Clinical Immunology: In Practice*, Shirai et al³ addressed the question of utility of FOT in severe asthma. The population studied using FOT was a reasonably broad cross-section of patients with asthma who attended clinics in an academic medical center. In this regard, they may be similar to populations reported in the US SARP⁴ and other large-scale studies of severe asthma. The key findings of the present study included FOT parameters that were associated with the expression of a severe asthma clinical phenotype. Because severe asthma can be difficult to discriminate from other forms of obstructive lung disease, these observations have potential clinical importance. However, several important limitations must be considered when interpreting these observations

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for implementation in clinical practice. First, the study population did not include patients with smoking-related COPD or other chronic obstructive lung diseases, and it is from these other forms of obstructive lung disease that the differentiation from severe asthma can be most difficult. Secondly, it is not clear from the study precisely what the added value of FOT to standard spirometric testing is in these patients, by receiver operating characteristics curve, positive and negative predictive value, and other statistical parameters. However, the authors did develop an FOT algorithm that defined a population enriched for severe asthma.

FOT can be used to assess bronchodilator responses. In a small study performed in Scotland, investigators found that FOT was as sensitive as spirometry in the detection of bronchodilator response in patients with moderate-to-severe COPD if tiotropium or aclidinium was added to their current regimen of inhaled corticosteroids plus long acting beta agonists.⁵

In a retrospective study of 234 subjects, including 133 patients with COPD and 101 healthy volunteers, FOT was compared with spirometry in both geriatric (≥ 65 years) and advanced elderly (≥ 80 years) groups. Significant increases in respiratory impedance (Z_5), resonant frequency (F_{res}), and respiratory resistance R_5 , R_{20} , R_5-R_{20} , and more negative respiratory reactance (X_5) were seen in both groups with COPD compared with healthy control subjects. R_5-R_{20} showed the best correlation with forced expiratory volume in 1 second in both groups. These data suggest that FOT has good performance when compared with spirometry for geriatric patients with COPD.⁶

FOT appears to have utility in other obstructive lung diseases. In a large, international, multicenter trial, investigators compared FOT, spirometry, and quantitative computed tomography chest imaging to examine its accuracy in correctly classifying the severity of COPD among patients. Baseline values of FOT and spirometry were compared with 3-month follow-up measurements in more than 2500 subjects. In general, the group with COPD had elevated R_5 , R_{20} , and X_5 when compared with smoking and nonsmoking controls. The investigators concluded that several parameters of FOT differ between smokers with COPD and nonsmoking volunteers and that these parameters can help classify airflow limitation as classified by the

American Thoracic Society (ATS)/European Respiratory Society (ERS)/Global Initiative for Obstructive Lung Diseases (GOLD) stages.⁷ FOT was used as a screening tool for airway disease in patients with respiratory symptoms exposed to World Trade Center dust. FOT in this patient population was able to detect significant airway disease in patients with normal spirometry. On the basis of these and other findings, Berger et al⁸ conclude that FOT is a useful screening tool for the diagnosis of early airway diseases.

The FOT is a novel means for measuring proximal and distal airway function that does not require a forced expiratory maneuver. Clinicians may find utility of FOT in children, the elderly, and in patients for whom forced expiratory spirometry is tiring or unreliable. Its added value in diagnosing or monitoring lung disease appears at present to be greatest in the obstructive lung diseases, particularly when quantitation of small airway function is desirable. Additional studies will further clarify the clinical role, added value, and appropriate uses for FOT in these and other pulmonary diseases.

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