CHEST

POINT:

Should Oscillometry Be Used to Screen for Airway Disease? Yes

Kenneth I. Berger, MD; Roberta M. Goldring, MD; Beno W. Oppenheimer, MD; New York, NY

ABBREVIATIONS: CAO = chronic airway obstruction; ECLIPSE = Evaluation of COPD Longitudinally to Identify Predictive Surrogate Endpoints; FOT = forced oscillation technique; FRC = functional residual capacity; WTC = World Trade Center

Detection of airway disease by physiologic testing was initially described using spirometry to determine vital capacity and expiratory airflow under maximal effort to distinguish obstructive from restrictive disease processes.[1] Subsequently, Dubois and colleagues[2] demonstrated direct assessment of airway resistance using plethysmography and in a separate publication described the precursor of the forced oscillation technique to measure respiratory system resistance.[3] This review addresses the question of whether direct assessment of resistance by forced oscillation provides diagnostic information equivalent or superior to standard assessment of airflow rates by spirometry.

The rationale and limitations of each technique are shown in Table 1. Spirometry measures airflow rates during forceful exhalation, but pressure remains unmeasured; thus, abnormalities in airway resistance are inferred based on the assumption of maximal effort. Ohm's law would dictate that assessment of airflow provides equivalent diagnostic information as direct assessment of resistance:

$$\left(Resistance = \frac{\Delta Pressure}{airflow}\right)$$

Although this assumption is likely valid for a system comprising a single airway, its utility may be limited in lungs, which contain a complex branching system of airways. The multiplicity of airways in the periphery produces an increasing cumulative cross-section area such that disease localized in small airways may not be apparent on spirometry (ie, the quiet zone) until the extent of disease is severe.[4] This limitation of spirometry may preclude early diagnosis because many respiratory diseases originate in the small airways. Therefore, optimal screening for airway disease should include testing modalities sensitive to disease localized in the lung periphery.

Oscillometry is a noninvasive test performed during tidal breathing. Pressure fluctuations of small magnitude (2-5 cm H_2O) are applied at the mouth, and the reflections of airflow and pressure are measured.[5,6] The relationship between airflow and pressure is analyzed to derive the respiratory system resistance (Table 2). Two additional features provide information beyond that available from spirometry. First, a parameter (reactance) can be derived that reflects respiratory system dynamic elastance (distensibility) and inertia. Second, assessment of parameters at multiple oscillation frequencies allows identification of nonuniformities in airflow distribution.[6,7] Because nonuniformities may be the only manifestation of small airway dysfunction, these parameters may allow identification of early disease. Thus, oscillometry allows for the diagnosis of small airway disease on screening evaluation analogous to the "gold standard" demonstration of frequency dependence of compliance by esophageal manometry.

Oscillometry Provides Diagnostic Information Not Evident on Spirometry

Subtle markers available on spirometry suggest the presence of small airway dysfunction. Reduction in midexpiratory airflows and reduction in expiratory reserve volume may occur prior to reduction in FEV_1. Although abnormality in these parameters define the presence of airway dysfunction, the site of disease remains unclear (ie, mild large vs severe small airway). In addition, these parameters may vary when patient effort and completion of the expiratory maneuver are inadequate. Notably, numerous studies demonstrated

AFFILIATIONS: From the Department of Medicine, Division of Pulmonary, Critical Care and Sleep Medicine, New York University School of Medicine; and André Cournand Pulmonary Physiology Laboratory, Bellevue Hospital.

CONFLICT OF INTEREST: None declared.

CORRESPONDENCE TO: Kenneth I. Berger, MD, New York University School of Medicine, 240 E 38th St, Room M-15, New York, NY 10016; e-mail: kenneth.berger@nyumc.org

DOI: 10.1378/chest.15-0106

TABLE 1] Comparison Between Spirometry and Oscillometry

Variable	Spirometry	Oscillometry
Measurement	Airflow and volume Pressure not measured Resistance assessed indirectly by airflow rates	Pressure and airflow Impedance calculated as: • Resistance • Reactance (dynamic elastance + inertia)
Maneuver	Maximal effort	Tidal breathing
Obstructive abnormalities		
Large airway dysfunction	Identified by reduction in airflow	Identified by increase in resistance
Small airway dysfunction	Relatively insensitive	Assessed by indexes of nonuniformity: • Frequency dependence of resistance • Reactance at low frequencies
Expiratory flow limitation during tidal breathing	Inferred when tidal expiratory flow approaches maximal flow	Directly assessed: • Inspiratory and expiratory reactance
Restrictive abnormalities		
Parenchymal disease	Detectable by spirometry	Not distinguishable from obstruction
Neuromuscular disease	Detectable by spirometry	Not assessed
Chest wall disease	Detectable by spirometry	Not detectable or appears similar to obstructive disease

the detection of airway disease by oscillometry, even when these subtle spirometric markers were normal.[6,8,9]

The enhanced diagnostic capabilities of oscillometry are evident in numerous studies. Abnormal oscillometry may identify pediatric and adult subjects with symptoms suggestive of either asthma or COPD, even in the setting of normal FEV_1 and normal midexpiratory airflow.[6,8] In addition, for patients with established airway disease, respiratory symptom severity and quality-of-life measures may correlate with oscillometry parameters that reflect small airway function rather than FEV_1.[8] Moreover, the presence of small airway dysfunction predicts subsequent loss of symptom control in patients with asthma.[8] Finally, improvement in small airway function during therapy is frequently noted on oscillometry but is not evident on FEV_1 or midexpiratory airflows.[10] Despite the lack of change in spirometry, the improved small airway function correlates with improved symptoms, airway and alveolar inflammation, and bronchial hyperreactivity.[11-13]

Lower Respiratory Symptoms Are Attributable to Small Airway Dysfunction

Bronchoprovocation testing provides a unique opportunity to assess simultaneous development of respiratory dysfunction and lower respiratory symptoms. Inhalation of methacholine has been shown to predominately alter small airway rather than large airway function.[14,15] During methacholine challenge testing, changes in

TABLE 2] Commonly Used Oscillometry Parameters

Parameter	Definition	Interpretation
Resistance (R)		
R at lowest oscillation frequency (eg, R_5)	Respiratory system resistance	Total respiratory resistance
R at high oscillation frequency (eg, R_{20})	Respiratory system resistance	Resistance of larger airways
Frequency dependence of resistance (eg, $R_{5\text{-}20}$)	Change in resistance with varying oscillation frequency	Nonuniform distribution of ventilation
Reactance (X)		
X at lowest oscillation frequency (eg, X_5)	Respiratory system elastance	Distensibility and nonuniformity
Resonant frequency (fres)	Oscillation frequency at which $X = 0$	Distensibility and nonuniformity
Reactance area (AX)	Area under reactance curve from X at lowest frequency to fres	Distensibility and nonuniformity