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COMMENTARY

Measurement of Respiratory System Admittance: A Straightforward Method, But a Difficult Interpretation

Commentary on the article by Nguyen et al. on page 348

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For many decades, there has been a need for simple, but specific and sensitive methods for measurement of the functional manifestations of respiratory diseases. The expression forced oscillation technique (FOT) relates to a group of methods applied to study the mechanical properties of the respiratory system, in which an external pressure or flow driving is used instead of relying on the action of the respiratory muscles (1). The measurement can be performed during spontaneous breathing, through low-resistance and moderate-dead space equipment, and accordingly it requires minimal cooperation from the investigated subject (2). Current measurement and computing technologies permit rapid measurements of the oscillatory impedance of the respiratory system (Zrs) by the simultaneous application of multiple oscillation frequencies (3) within a short (10–20 s) recording time, or the tracking of Zrs at a single frequency (4). The former approach allows an estimation of the frequency dependence of Zrs, and hence inferences concerning the mechanical properties of the central and peripheral parts of the lungs, whereas single-frequency measurements offer a fine temporal resolution to reveal the within-breath variations in Zrs (4). These features and its noninvasive nature make the FOT a unique lung function test that is particularly attractive in subjects with a limited ability to cooperate, such as young children (5,6).

One of the most complicated and widely addressed methodological problems of the FOT is the shunt effect of the upper airway walls. In the most common setting of the FOT, where the oscillations are applied at the mouth, and both pressure and flow are measured at the airway opening (*i.e.*, measurement of the input impedance of the respiratory system), part of the oscillatory flow is lost across the vibrating upper airway walls. In other words, the measured input Zrs corresponds to the *parallel* arrangement of the "true" shunt-free respiratory impedance (Zrs*) and the upper airway wall impedance (Zuaw). The shunt effect exerted by Zuaw leads to misestimation of Zrs* by Zrs (7,8), which becomes particularly marked either when Zuaw is low (as with unsupported, freely-vibrating cheeks) or when Zrs* is high (as in airway obstruction). The changes in Zrs* due to any bronchoactive process may be reflected by the changes in Zrs in a much distorted manner, and thus no conclusion can be drawn as to the bronchial dimensions. The magnitude and phase distortion due to the shunt effect of Zuaw may result in the strange situation in asthmatics, where the total respiratory reactance (Xrs) has been found to correlate with the pulmonary resistance better than does the resistance (Rrs) (9). It is not surprising, therefore, that the history of the FOT is characterized by a sequence of heroic efforts to eliminate, minimize or account for this upper airway artifact, which has proven to be the major, if not the only obstacle in the routine use of this very convenient and informative method. It became obvious very early on that, however firmly the cheeks and the mouthpad are supported by the palms of the measured subject or, in the case of young children, those of the assistant, the shunt effect cannot be eliminated completely and therefore will remain an unpredictable and unstable source of error (7,10). Theoretically, Zuaw can be measured during a Valsalva maneuver and can be corrected for (11), but this procedure has proved impractical in most routine settings. Peslin and colleagues realized that, if the inside and outside of the upper airways are exposed to the same pressure oscillations, the zero transmural pressure will eliminate the shunt flow (12). This condition can be attained by using a canopy enclosing the head and the upper neck of the subject (the "head generator"), with the pneumotachograph attached to the mouthpiece and subject to the same pressure field as the surface of the head and the upper neck. Although the inaccuracies in the measurement of Zrs* associated with this method are far less significant than the artifacts related to the standard technique, the inconvenience of the setting, the inaccessibility of the airway opening and the risk of claustrophobia preclude the widespread use of head generators, especially in pediatric lung function testing.

The study published by Nguyen *et al.* (13) in the present issue of Pediatric Research follows a completely different approach to circumvent the upper airway artifacts. The underlying idea is the use of the total respiratory admittance (Ars) instead of Zrs (14). Ars is the reciprocal of Zrs, and its upper

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airway wall component (Auaw) and lower respiratory system component (Ars*) are arranged *in series*. The significance of this situation is that Ars* is an additive component of Ars, and any change in Ars* will appear in Ars uneffected by the upper airway shunt. Accordingly, in all investigations where the alterations in the respiratory mechanical properties may be more important than their absolute values, as in bronchodilator or bronchoconstrictor tests, there is an appealing advantage of the measurement of Ars.

However, there is an obvious interpretational burden inherent in the admittance approach. Although some familiarity is needed with complex numbers and the manner in which they describe the mechanical properties of the respiratory system, the concept of impedance is fairly straightforward. Rrs, the real part of the complex Zrs, characterizes all the resistive (dissipative) losses that take place in the airways and the respiratory tissues, whereas the imaginary part (Xrs) is determined by two major energy storage mechanical components that are opposite nature, *i.e.*, the elasticity of the tissues and the inertia of the air column in the bronchi. The elastic reactance predominates during slow respiratory movements, while the inertial reactance becomes significant with increasing oscillation frequencies, and these two cancel each other out at the resonant frequency, where the behavior of the respiratory system is purely resistive (1). The concept of admittance is far less plausible, since its real and imaginary parts are determined by both dissipative and storage properties. However, if the measurements are made near the resonant frequency, as was done by Nguyen *et al.* by selecting 12 Hz as the oscillation frequency in the 3.5–7.5-yr-old children (13), Ars will represent the flow conductance of the total respiratory system, and will correspond closely to its predominating component, the bronchial conductance. Further studies are needed to ascertain whether or not the admittance method can be "tuned" to the resonant frequency, where this straightforward interpretation of Ars and its change pertains. However, it appears that the difficulties of understanding in the evaluation of admittance data are more than offset by the advantages of the conventional FOT, which are preserved in the admittance approach and are particularly important in studies on young children; these are the noninvasivity, the minimal cooperation requirement and the ease of performance of the measurement.

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