of MPs so as to support public health efforts to limit the most toxic MPs and, to the extent that they will unlikely ever be fully eliminated, offer some reasonable avenues for mitigating interventions at a personal level. Further studies to replicate the concerns of nylon 6.6 highlighted above, to test other MPs in more advanced model systems, and to understand the specifics of leachate composition driving airway toxicity are urgently needed. ■

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# Real-World Application of Oscillometry: Taking the LEAD

Spirometry is regarded as the gold standard of measurement of pulmonary function. However, spirometry has a major limitation, which is that it is effort dependent. In addition, the act of taking a deep breath to perform spirometry may affect the very measurement being made, a type of "observer effect" well described in quantum mechanics. Yet, there is another way of assessing lung function that minimizes these limitations, known as the forced oscillation technique, or oscillometry. First described by Dubois and colleagues in 1956 (1), oscillometry involves imposing an oscillating flow signal during quiet breathing. The subsequent pressure and flow measured at the mouth reflect the mechanical impedance of the respiratory system, which in turn can be related to ($R$), airflow and tissue resistance and heterogeneity, and ($X$), reactance, the apparent stiffness of the respiratory system related to lung volume, lung and chest wall compliance, and ventilation heterogeneity (2). Originally a research tool, oscillometry has gained considerable attention in the last two decades with the introduction of commercially available instruments (3), the publication of updated technical standards (2), and renewed enthusiasm for an old technique (4). However, despite many reports of oscillometry in different disease settings, there remain gaps in the evidence to support using oscillometry on a larger clinical scale (5).

This is where the study published by Veneroni and colleagues in this issue of the *Journal* (pp. 444–453) has substantial impact (6). The authors report the results of oscillometry performed on participants in the Austrian LEAD (Lung, Heart, Social, Body) study (7). The LEAD study included a random sample of residents of Vienna and Lower Austria. Data were collected on respiratory symptoms (wheezing, breathlessness, and cough) and patient-reported diagnosis of lung disease (asthma, chronic obstructive pulmonary disease [COPD], or chronic bronchitis). Oscillometry was measured using a commercial device and standardized methods, followed by spirometry. Overall, 20% of 7,560 participants had abnormal oscillometry, defined as any one parameter of inspiratory and expiratory $R_5$ and $X_5$, ($R$ and $X$ at 5 Hz) or $AX$ being outside the 5th–95th percentile range based on published reference values (8) or tidal expiratory flow limitation (EFLt) $>$ 2.8 (9). In comparison, 13% of all participants had abnormal spirometry. A Venn diagram nicely illustrated how spirometry and oscillometry complemented each other, and adding oscillometry uncovered an additional 17% of participants with respiratory symptoms or lung disease with abnormal lung function despite normal spirometry. Interestingly, 16% of all participants had abnormal spirometry and/or oscillometry and no respiratory symptoms or disease.

The odds of having abnormal oscillometry increased with the number of symptoms or with reported respiratory disease, with $X_5$ being more likely to be abnormal than $R_5$ and outcomes of $AX$



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being comparable to $X_5$. EFLt was associated with the highest risk of having symptoms or respiratory disease. Findings were similar if only participants with normal spirometry were included. Additional observations were made regarding patterns of abnormal oscillometry and underlying symptoms or disease. For example, EFLt was strongly related to breathlessness or COPD. Abnormal expiratory parameters were more likely in participants with COPD. Importantly, as reference values vary by type of instrument and population, a sensitivity analysis confirmed similar findings when using a different instrument and reference set (10).

How does this study influence the evidence supporting a clinical role for oscillometry? First, it is the largest epidemiological study to date to relate oscillometry to respiratory symptoms and diagnoses in a general population across a wide age range (18–90 yr). Many studies have examined oscillometry in different disease states (5), but none has involved using oscillometry at such a large scale. The forest plots of odds ratios show clear association between increased odds of abnormal oscillometry as the number of symptoms increases or respiratory disease is present, even in those with normal spirometry. Another, larger, recent epidemiological study also showed a similar prevalence of abnormal oscillometry (16%) but a slightly higher prevalence of abnormal spirometry (19%) (11). Of note, this larger study involved a narrower age range (50–64 yr), a different instrument used, and different definitions of normal and reference values. Nevertheless, together these two studies validate the clinically relevant diagnostic potential of oscillometry, even when spirometry is normal.

Second, the results provide insight into the potential mechanisms of symptoms and disease. For example, the finding of expiratory parameters being more common in COPD likely reflects the more important role of loss of lung recoil, rather than increased airway resistance, contributing to expiratory flow limitation. The finding of EFLt being particularly associated with symptoms and disease emphasizes the significance of flow limitation occurring during quiet tidal breathing. These are insights that cannot be gained by routine spirometry.

Third, this study provides practical guidance on how we might simplify reporting oscillometry. The many parameters involved can be daunting to clinicians. The current study supports using $X_5$ or $AX$ as perhaps the most useful parameters. Even though $AX$ may be a more robust parameter, because it integrates data from multiple frequencies, $X_5$ may be sufficient, allowing oscillometry to be useful at just a single frequency.

Of course, there are limitations. As acknowledged by the authors, there are methodological issues that must be considered, and there was only subjective reporting of symptoms and diagnoses by participants. One issue not discussed is the lack of adjustment of parameters for lung volume, which is an inherent shortcoming of oscillometry (12), although some studies are beginning to incorporate lung volumes to address this problem (13). The influence of smoking as a modifiable risk factor for symptoms and disease was not investigated. The group of participants with abnormal spirometry and/or oscillometry yet without symptoms or diagnosis was left unexplained. Finally, to really appreciate the clinical utility of oscillometry, we need longitudinal data to determine how well oscillometry tracks respiratory symptoms and disease status, detects response to therapy, and predicts disease development. However, the results of the current study certainly LEAD the way in validating oscillometry as an important complementary, and advantageous, tool to spirometry in the assessment of respiratory symptoms and diagnosis of lung disease. ■

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