



Letters

Oscillometry for acute asthma in the pediatric emergency department

A feasibility study

Acute asthma exacerbations account for 750,000 pediatric emergency department (ED) visits, 200,000 hospitalizations, and 5.2 billion in excess health care costs in the United States annually.¹ The current ED treatment of acute exacerbations is based on the severity at initial presentation as determined by clinical scoring tools, which are limited by subjectivity and poor association with actual airway function.² Traditional methods to objectively assess lung function, including spirometry and peak expiratory flow rate, are not feasible or reproducible in younger children.^{3,4} Peak expiratory flow rate also tends to underestimate worsening lung function.⁵ Consequently, ED treatment is variable, leading to inefficient use of asthma therapies, prolonged ED length of stay, and unnecessary hospitalizations.⁶

Oscillometry, a noninvasive method to assess lung function, has the potential as an objective marker of the severity of acute asthma exacerbation and treatment response in the ED setting. Oscillometry is performed using a handheld device that applies external oscillatory signals in the mouth during normal tidal breathing to measure respiratory system impedance.⁷ Studies have found that oscillometry is feasible and reproducible in preschool-aged children in the outpatient setting; however, evaluations of oscillometry in the ED are limited.^{8,9} The aim of our study was to assess the feasibility and responsiveness of oscillometry, using tremoFlo c-100 (Thorasys, Montreal, Quebec, Canada), in the ED management of children with acute asthma exacerbations. TremoFlo c-100, or air-wave oscillometry, is a new device that uses a combination of sine waves at multiple discrete frequencies to generate volume perturbations to measure respiratory impedance. TremoFlo is also portable and fast, making it ideal for clinical applications in the ED setting.

We performed a feasibility study of 20 children aged 4 to 18 years, presenting to an urban tertiary care children's hospital ED for an acute asthma exacerbation. Children with comorbid illnesses were excluded. Vital signs, pulmonary asthma score (PAS) (a

15-point clinical exacerbation severity score), and respiratory impedance by oscillometry were collected 3 times as follows: (1) before receiving any treatment (in 19 of 20); (2) after completion of initial therapies (combined nebulized albuterol and ipratropium bromide and oral corticosteroids); and (3) 2 hours after initial therapies or at disposition. Treating physicians were blinded to oscillometry measurements to minimize bias in management decisions.

Respiratory impedance, as measured by tremoFlo c-100, has 2 components, resistance (R) and reactance (X), which are measured at a range of oscillation frequencies (5–37 Hz and 7–41 Hz). Low-frequency R (5 or 7 Hz) indicates total airway resistance, and low-frequency X indicates lung tissue stiffness that has been correlated with peripheral airway obstruction.⁷ We performed 3 to 5 oscillometry measurements at each time point, and the mean values from 3 acceptable measurements were recorded. An acceptable assessment includes 3 measurements with a low-frequency R coefficient of variation (CV) (a marker of test reproducibility) of less than or equal to 15%.⁹ Respiratory impedance data were normalized using z-scores from previously published reference equations based on height and sex.¹⁰

We initially obtained 20-second measurements at a frequency range of 5 to 37 Hz. To improve the feasibility of oscillometry in the ED setting, we reduced the measurement duration to 13 seconds for the previous 7 participants. We also changed the frequency range to 7 to 41 Hz to evaluate for less interference in children with higher respiratory rates. We analyzed respiratory impedance data at 11 Hz for consistency, because this frequency was measured in all participants.

Participants had a mean age of 9.3 ± 3.9 years; 50% were boys, and 30% were African American. The mean initial oxygen saturation was $95.1 \pm 2.6\%$; the initial PAS was 8.4 ± 2.1 , indicating moderate exacerbation severity. The mean ED length of stay was 4.2 ± 1.6 hours; 35% of the participants required continuous albuterol, and 15% were admitted. The median (interquartile range) time from ED triage to initial oscillometry assessment was 31.0 (15.8, 40.0) minutes, and the mean time between time points 1 and 2 and time points 2 and 3 were 50.5 ± 19.6 minutes and 118.3 ± 35.3 minutes, respectively.

Most participants (75%) successfully completed the initial oscillometry assessment. However, 2 participants were unable to perform the initial oscillometry assessment because of the severity of exacerbations; both were able to complete subsequent assessments. Notably, 3 participants completed the initial assessment but did not have acceptable measurements with a CV of greater than 15%. The mean number of measurements required at each

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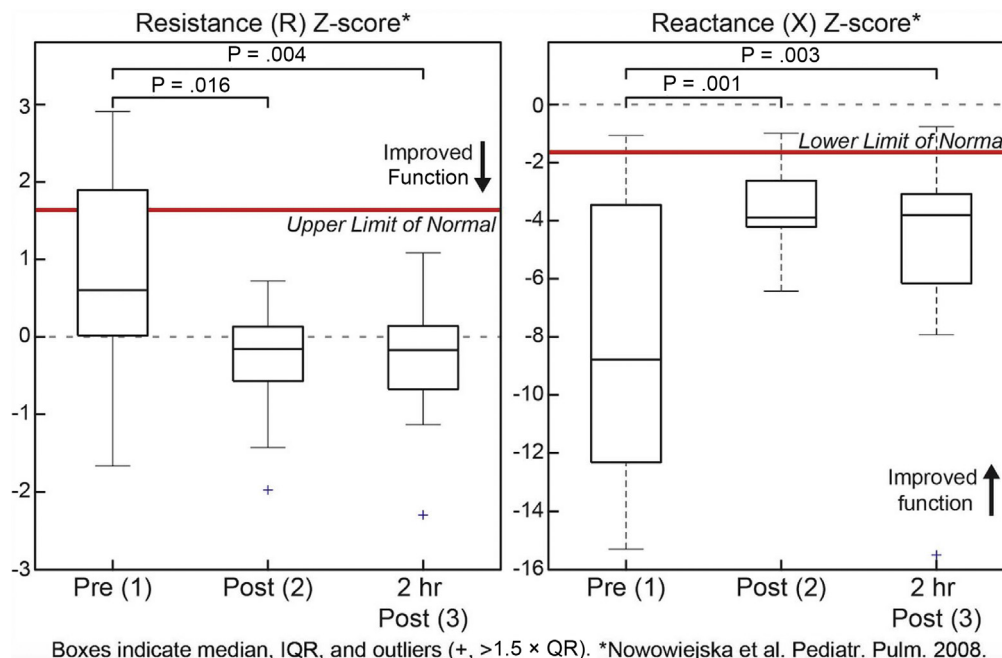


Figure 1. Change in z-score of R11 and X11 across ED course time points. ED, emergency department; IQR, interquartile range; R11, resistance at 11 Hz; X11, reactance at 11 Hz.

assessment was 3.9 ± 0.8 . Across all time points, low-frequency R CV was 10.9 (6.6, 15.4). There was no difference in the percentages of children who were able to successfully complete the initial oscillometry assessment in those evaluated with 20 seconds per 5 to 37 Hz compared with those evaluated with 13 seconds per 7 to 41 Hz measurements ($P > .99$). No adverse events were reported.

There were statistically significant differences in z-scores for resistance at 11 Hz (R11) and reactance at 11 Hz (X11) between time points 1 and 2 and 1 and 3 but not between time points 2 and 3 (Fig 1). After the completion of initial therapies, R decreased and X increased—the change in R11 was -16% (-37% , -6%) and the change in X11 was 48% (18% , 64%)—indicating improved lung function. Between time points 2 and 3, the change in R11 was -5% (-14% , 7%) and the change in X11 was -10% (-19% , 14%). There was also a significant difference in PAS between time points 1 and 2 (difference -1.8 ; $P = .001$), but not between time points 2 and 3. There was no significant correlation between PAS and either R11 and X11 at any time point or a percentage change in PAS and R11 and X11 between the time points.

The results of our study illustrate that oscillometry is feasible, responsive, and safe in children with acute asthma exacerbations in the ED. To the best of our knowledge, this study is the first to investigate the use of tremoFlo c-100 in the ED assessment of children with acute exacerbations. We made adaptations, which improved the feasibility of performing oscillometry assessments in the ED and did not affect the quality of measurements. We observed considerable improvement in raw and z-score values of R and X after initial ED asthma therapies. The change in z-score of X was greater than that of R, suggesting that reactance may be a better marker of airway obstruction in children with acute exacerbations. Interestingly, there was no substantial change in R and X during the 2 hours after completion of initial therapies, suggesting that most of the changes in lung function occur in the first hour, which may, in turn, contribute to expedited ED decision making. Finally, we found no correlation between the PAS and either R and X, but we speculate that the clinical severity score and oscillometry measurements may represent different domains of an acute asthma exacerbation.

Our study has a few limitations. First, the interpretation of respiratory impedance values is relative to normative values in a healthy population, and reference equations have not yet been developed for tremoFlo. Second, owing to the small sample size, we were unable to draw meaningful inferences regarding the association of oscillometry measures and ED clinical outcomes. A larger trial is needed to establish the validity of oscillometry in determining ED clinical outcomes. Oscillometry may be a valuable bedside measure of lung function to direct ED treatment and disposition decisions and may also reduce the clinical morbidity associated with asthma.

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