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## Oscillometry for Acute Asthma in the Pediatric Emergency Department: A Feasibility Study

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### Keywords

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

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Oscillometry, a noninvasive method to assess lung function, has potential as an objective marker of acute asthma exacerbation severity and treatment response in the ED setting. Oscillometry is performed using a handheld device that applies external oscillatory signals at the mouth during normal tidal breathing to measure respiratory system impedance.<sup>7</sup> Studies have shown oscillometry to be feasible and reproducible in pre-school aged children in the outpatient setting, but evaluations of oscillometry in the ED are limited.<sup>8,9</sup> The aim of our study was to assess the feasibility and responsiveness of oscillometry, using tremoFlo c-100 (Thorasys, Montreal, QC, Canada), in the ED management of children with acute asthma exacerbations. TremoFlo c-100, or airwave 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 application in the ED setting.

We performed a feasibility study of 20 children aged 4–18 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 (15-point clinical exacerbation severity score), and respiratory impedance by oscillometry were collected three times: 1) prior to receiving any treatment (in 19 of 20), 2) after completion of initial therapies (combined nebulized albuterol/ipratropium bromide and oral corticosteroids); and 3) 2 hours post-initial therapies or at disposition. Treating physicians were blinded to oscillometry measurements to minimize bias in management decisions.

Respiratory impedance, as measured by the tremoFlo c-100, has two components, resistance (R) and reactance (X), that 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.<sup>7</sup> We performed 3–5 oscillometry measurements at each timepoint; the mean values from three acceptable measurements were recorded. An acceptable assessment includes three measurements with a low frequency R coefficient of variation (CV), a marker of test reproducibility,  $\leq 15\%$ .<sup>9</sup> Respiratory impedance data were normalized using z-scores from previously published reference equations based on height and gender.<sup>10</sup>

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

Participants were  $9.3 \pm 3.9$  years, 50% male and 30% African American. Initial oxygen saturation was  $95.1 \pm 2.6$  percent, initial PAS was  $8.4 \pm 2.1$  indicating moderate exacerbation severity, ED length of stay was  $4.2 \pm 1.6$  hours, 35% required continuous albuterol, and 15% were admitted. There were 31.0 (15.8, 40.0) minutes from time of ED triage to initial oscillometry assessment,  $50.5 \pm 19.6$  minutes between timepoints 1 and 2, and  $118.3 \pm 35.3$  minutes between timepoints 2 and 3.

The majority (75%) of participants successfully completed the initial oscillometry assessment. Two participants were unable to perform the initial oscillometry assessment due to severity of exacerbations; both were able to complete subsequent assessments. Three completed the initial assessment but did not have acceptable measurements with CV > 15%. The mean number of measurements required at each assessment was  $3.9 \pm 0.8$ . Across all timepoints, low frequency R CV was 10.9 (6.6,15.4). There was no difference in percentage of children able to successfully complete the initial oscillometry assessment in those evaluated with 20 second/5–37 Hz compared to 13 second/7–41 Hz measurements ( $p=1.00$ ). No adverse events were reported.

There were statistically significant differences in z-scores for R11 and X11 between timepoints 1 and 2 and 1 and 3, but not between timepoints 2 and 3 (Figure 1). After completion of initial therapies, R decreased and X increased: R11 = -16% (-37%, -6%) and X11 = 48% (18%, 64%), indicating improved lung function. Between the second and third timepoints, R11 = -5% (-14%, 7%) and X11 = -10% (-19%, 14%). There was also a significant difference in PAS between timepoints 1 and 2 (difference -1.8;  $p=0.001$ ), but not between timepoints 2 and 3. There was no significant correlation between PAS and either R11/X11 at any timepoint, or percent change in PAS and R11/X11 between timepoints.

The results of our study demonstrate that oscillometry is feasible, responsive, and safe in children with acute asthma exacerbations in the ED. To our knowledge, this study is the first to investigate the use of the 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 X was greater than R suggesting that reactance may be a better marker of airway obstruction in children with acute exacerbations. Interestingly, there was no significant change in R/X during the two hours after completion of initial therapies suggesting the majority of change in lung function occurs in the first hour, which may contribute to expedited ED decision-making. Lastly, we found no correlation between the PAS and either R/X, but we speculate that the clinical severity score and oscillometry measurements may represent different domains of an acute asthma exacerbation.

Limitations of our study include that interpretation of respiratory impedance values is relative to normative values in a healthy population and reference equations have not yet been developed for the tremoFlo. In addition, due 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 reduce the clinical morbidity associated with asthma.

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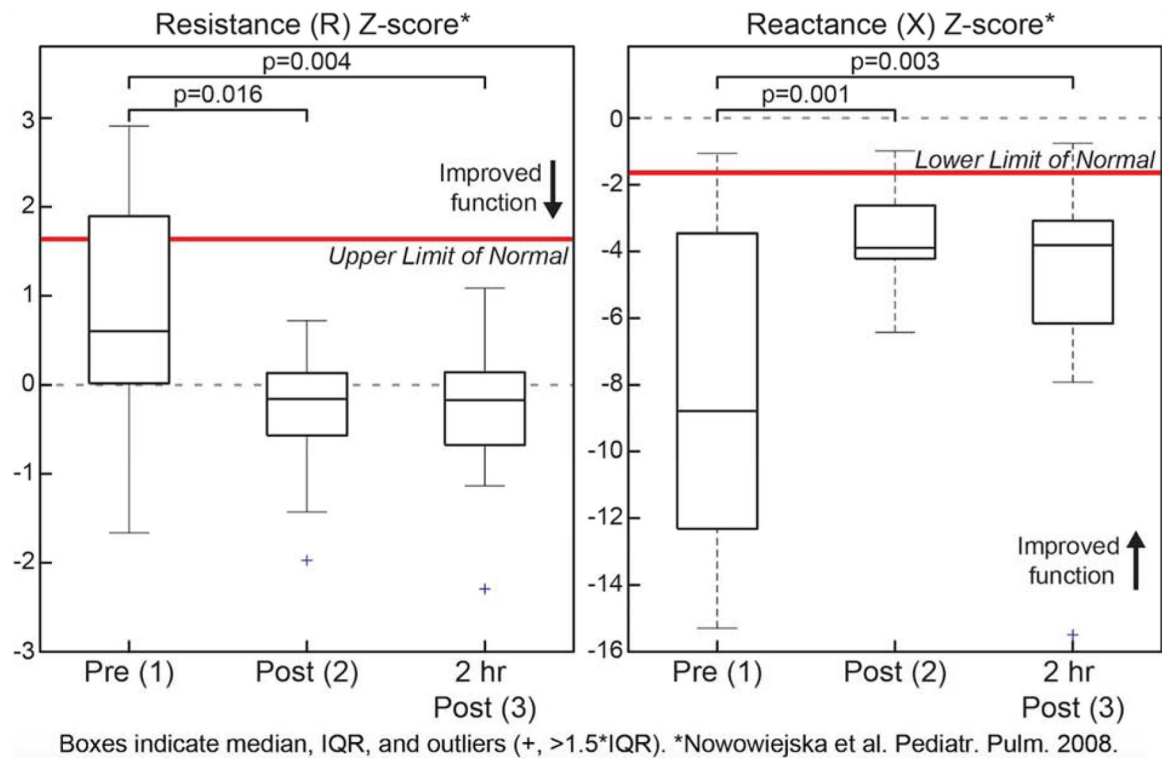
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## Abbreviations:

<b>ED</b>	Emergency department
<b>FOT</b>	Forced oscillation technique
<b>R</b>	Resistance
<b>X</b>	Reactance
<b>PAS</b>	Pulmonary Asthma Score
<b>CV</b>	Coefficient of variation

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**Figure 1.**  
Change in Z-score of R11 and X11 across ED course timepoints.