On the Relationship of Airway Impedance and Ventilation Abnormalities in Moderate and Severe Asthmatics

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Introduction and Objectives: Asthma is an inflammatory airway disease that leads to heterogeneous lung ventilation that is thought to be directly related to airway constriction, resistance and reactance. In asthmatics, ventilation heterogeneity has been studied using multi-breath gas washout tests, the forced oscillation technique (FOT), pulmonary magnetic resonance imaging (MRI), and computational modelling. First described over 60 years ago, our understanding of FOT measurements is based on the notion that the lungs are comprised of a linear dynamic system of airways and alveoli. Impedance to airflow (including both resistance and reactance) can be considered as analogous to impedance of an electric current passing through resistors and capacitors in a circuit. Currently, pulmonary FOT measurements may be readily acquired without patient effort using a handheld device that applies low-amplitude pressure oscillations at the mouth as the patient breathes normally. Here we aim to experimentally measure airway impedance using FOT in moderate-severe asthmatics and compare these directly with simulations derived using an asymmetric branching airway tree model.

We hypothesized that resistance and reactance measured using FOT would be strongly related to airway tree model predictions when functional MRI data are incorporated into the model.

Materials and Methods: Participants with a diagnosis of asthma provided written informed consent to approved protocols and underwent pulmonary function tests (including FOT) and hyperpolarized noble gas MRI to generate ventilation defect percent (VDP) as previously described. MRI ventilation maps were co-registered to the airway tree model and airways proximal to ventilation defects were constricted. Model predictions of resistance and reactance at 5Hz (to probe the small airways) were generated for each participant as previously described and compared to the values measured using FOT. Data were tested for normality with the Shapiro–Wilk test and non-parametric tests were performed because the data did not satisfy the normal distribution. Spearman correlations were used to evaluate univariate relationships. All statistics were performed using SPSS 24.0 (IBM, Armonk, NY).

Results and Discussion: We evaluated 34 moderate-severe asthmatics. FOT-measured resistance was weakly but significantly correlated with VDP (ρ=0.3, p=0.03) while FOT-measured reactance was significantly correlated with VDP (ρ=-0.5, p=0.001) and model-predicted reactance (ρ=0.5, p=0.003). Subjects with highly elevated VDP (>20%) appear to have greater simulated values of resistance and reactance as compared to experimental measurements, but this has only been observed in a small group of subjects, and is not yet statistically significant. This finding may be related to the presence of larger ventilation defects, which may involve the larger airways and provide a deeper understanding of asthma-structure-function relationships.

References: