A distinguishing feature of asthmatic lungs is that, when provoked, the airways constrict heterogeneously [1]. However, the tools typically used to study ventilation heterogeneity in humans, i.e., measurement of lung mechanics [2] and multiple-breath inert gas wash-out [3], provide only global and implicit assessment of the functional impact of structural changes. Since airways constitute the paths by which ventilation reaches the alveoli, heterogeneous narrowing of the airways should lead to correspondingly non-uniform ventilation distributions. Far more insightful, then, are image-based methods that can provide quantitative information on the spatial characteristics and heterogeneity of ventilation.

Imaging techniques for mapping ventilation distribution such as x-ray computed tomography [CT] [4] and positron emission tomography [PET] [5] have the drawback of ionizing radiation exposure. Imaging ventilation distribution in subjects using hyperpolarized [HP] $^3$He MRI [6-8] utilizes no ionizing radiation, and published images to date clearly depict how heterogeneous airway constriction in asthmatics results in patchy ventilation defects distributed throughout the lung [10-15]. Recent studies using HP $^3$He MRI to evaluate asthmatics include assessment of their response to methacholine challenge and exercise challenge [12], correlation with clinical severity and spirometry [10], and assessment of the variability of regional airflow obstruction [11].

Assessment of ventilation distributions have typically been done by subjective scoring or by identifying and/or counting the number of defects [7] [9-11], and comments on their homogeneity/heterogeneity have typically remained qualitative in nature [6] [12-15]. The combination of the wash-in approach used in animals with HP $^3$He MRI to quantitatively map ventilation [16], while rigorous, cannot be readily extended to human studies due to the required quantity and cost of the $^3$He gas necessary, as well as higher safety requirements.

We review approaches to quantifying the distribution and heterogeneity of ventilation using HP $^3$He MRI in a manner applicable to asthmatic subjects. Interrogating imaging data with impartial algorithms reduces the uncertainties associated with human judgment. Numerical methods have been developed to quantify and characterize the development of ventilation heterogeneity in HP $^3$He ventilation MR images acquired from asthmatic subjects. HP $^3$He MRI ventilation has also been quantified in studies employing mouse models of asthma [17-18].

HP $^3$He MRI has also been used to visualize the airways by acquiring the MR images as the gas travels down the respiratory airway tree [18-23]. Successive scans using dynamic HP $^3$He MRI can capture the disappearance or constriction of airways following a MCh challenge in asthmatic subjects. The observation that ventilation dropouts correlate with
low airway signal in HP $^3$He MRI raises the interesting question of whether or not such structure-function relationships could be established and quantified.

REFERENCES


