MRI Ventilation Defects in Asthma: Space and Time Explorations of Non-randomness

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Purpose: The spatial distribution of constricted airways in asthma throughout the lungs was originally described as random, which suggests a ventilation impairment pattern that is diffuse and homogeneous during an asthma attack, where the airways constrict. Pulmonary imaging, namely the advent of functional magnetic resonance imaging (MRI), has generated paradigm shift in this understanding towards a disease that is spatially heterogeneous and temporally persistent. Hyperpolarized noble gas MRI studies have revealed localized ventilation defects (1) that increase after bronchoconstriction (2) and respond to treatment with bronchodilation (3). A longitudinal study of asthma employing hyperpolarized noble gas MRI has not yet been performed, therefore the objective of this study was to evaluate asthmatic patients over a long period of time using MRI to evaluate long-term reproducibility of ventilation defects. We hypothesized that ventilation defects will be in the same spatial location at longitudinal follow-up.

Materials and Methods: Patients with a clinical diagnosis of asthma provided written informed consent to approved protocols (separate ones for each visit) and were evaluated using spirometry and hyperpolarized $^3$He MRI at baseline, post-methacholine and post-salbutamol during visit one (V1) and at baseline and post-salbutamol during visit two (V2). Spirometry was performed according to ATS guidelines (4) and MRI was acquired using a 3.0 Tesla MR750 system (General Electric Healthcare, Milwaukee, WI, USA) as previously described (5) to generate VDP (6). The differences between baseline spirometry and MRI measurements between visits were evaluated with paired t-tests using SPSS 23.0 (IBM Corporation, Armonk, NY, USA). V1 baseline and post-methacholine MR images were spatially and qualitatively compared to baseline V2 MR images.

Results: In this interim analysis, we evaluated eight patients with mild-moderate asthma at V1 and V2 at 6 years ± 6 months after V1. Quantitatively, there were no significant differences between V1 and V2 spirometry and MRI measurements. Qualitatively, however, four patients had homogenous ventilation patterns at both visits, while two patients had visually less and smaller ventilation defects. The remaining two patients had visually more and larger ventilation defects. For all patients, the spatial distribution of ventilation and ventilation defects remained similar from V1 to V2, such that ventilation defects remained in the same spatial locations over time.

Conclusion: Different patients underwent different changes in ventilation between V1 and V2. Importantly, however, for patients with ventilation defects that were present at V1, these ventilation defects persisted in the same spatial locations. This preliminary result suggests that asthma is not random, but deterministic in nature.

References: