Hyperpolarized Helium-3 MR Lung Ventilation Imaging in Asthmatics: The Temporal Characteristics of Ventilation Defects

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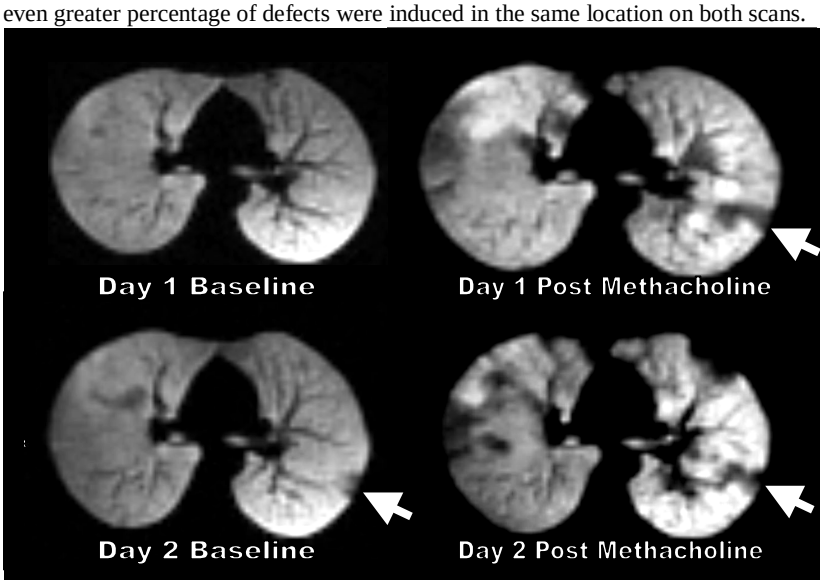
Introduction: Asthma is a disease characterized by reversible airflow obstruction. With hyperpolarized helium-3 MR techniques (H3HeMR) the regional ventilation of the lung can be imaged. Ventilation defects have been demonstrated in asthmatics at baseline (1). Inhaled methacholine is a direct bronchoconstrictor and the number of ventilation defects has been shown to increase following methacholine inhalation in asthmatics (2) The purpose of this study was to assess the temporal characteristics of these ventilation defects in individual asthmatics.

Methods and Materials: Seven mild asthmatics (age 19-21 years) underwent H3HeMR before and after the administration of methacholine on two separate occasions between 1 and 31 weeks apart (mean 16 weeks), referred to as imaging Day 1 and Day 2. MR imaging was performed on a 1.5T (Siemens Medical Solutions, Malvern, PA) modified by addition of a broadband radio-frequency amplifier and a flexible ^{3}He chest radio-frequency coil (IGC Medical Advances, Milwaukee, WI). Helium-3 gas was polarized by collisional spin exchange (Model 9600 Helium Polarizer; Amersham Health, Durham, NC). Approximately 300 ml of 15%-35% polarized H3He gas diluted with medical grade nitrogen to make a total volume of one L was inhaled by the subjects. MR was performed during 15-20 sec breathold using a FLASH sequence as follows: 19-28 axial 10 mm thick image sections with no gap, TR/TE 7/3 ms; flip angle 10^o; matrix, 80 x 128; FOV 26 x 42 cm. Spirometry (Renaissance, Puritan-Bennett, Lenexa, KS) was performed before imaging and after methacholine administration. The total number of ventilation defects was assessed for each study by a consensus of two readers. The mean number of defects per slice (MNDS) was computed for each of the four studies from each subject. In addition, the four studies from each subject were compared pair-wise to determine the number of defects present on both studies. Defects that were present in the same location on two studies were called persistent. The percent of defects persisting was calculated by dividing the number of persistent defects by the number of defects on the first of the two studies.

Results: At baseline the average MNDS for the 7 subjects was 2.2 on Day 1 and 1.2 on Day 2 (p=0.20). Following methacholine administration, the MNDS increased to 6.0 (p=0.0064, compared to baseline) on Day 1 and to 5.7 (p=0.0029, compared to baseline Day 2) on Day 2. The correlation coefficients of baseline spirometry with baseline MNDS were: 0.41 (FVC %pred), 0.33 (FEV1 %pred), 0.04 (FEV1/FVC), 0.13 (FEF 25-75 %pred). The correlation coefficients of post methacholine spirometry and post methacholine MNDS were: 0.73 (FVC %pred), 0.71 (FEV1 %pred), 0.53 (FEV1/FVC), 0.60 (FEF 25-75 % pred). The correlation coefficient of the change in spirometry values to the change in MNDS from baseline to post methacholine were 0.26 (FVC %pred), 0.57 (FEV1 %pred), 0.74 (FEV1/FVC), and 0.69 (FEF 25-75 % pred) for both days. The percent of defects on the baseline scan persisting on the post methacholine scan was 69% (sd 25%) on Day 1 and 82% (sd 16%) on Day 2 (p=0.17). Comparing the baseline scan on Day 1 with the baseline scan on Day 2, 39% (sd 32%) of defects persisted or recurred in the same location. Comparing the post methacholine scans from Day 1 and Day 2, 63% (sd 12%) of defects present on the day 1 scan were present on the Day 2 scan.

Discussion: There was no significant difference in the MNDS between Day 1 and Day 2 baselines or following methacholine, but, there was a significant increase in the number of defects from baseline to the post methacholine scans on both days. There was relatively poor correlation of the baseline spirometry with the baseline MNDS, perhaps because all subjects had normal spirometry and few defects at baseline. A positive correlation of MNDS with baseline spirometry in asthmatics with a larger spectrum of disease has been found previously (3). The correlation of change in spirometry with the change in defect number was stronger. The strongest correlations were found between the post methacholine spirometry and the post methacholine MNDS, suggesting the ventilation defects seen on H3He MR reflect airflow obstruction in asthmatics. The most interesting result was that 39% of defects present at baseline persisted or recurred in the same location on a second scan done weeks to months later. Furthermore, an even greater percentage of defects were induced in the same location on both scans.



Conclusion: As expected a large percentage of defects present at baseline persisted on a post methacholine scan. Interestingly, almost 40% of defects present at baseline persisted or recurred in the same location on a second baseline scan performed 1 to 31weeks later. Furthermore, regions of the lung that bronchoconstricted following methacholine on the first imaging day were likely to constrict on the second imaging day as well. These findings suggest that asthma is a heterogeneous disease and that some areas may be more prone to bronchoconstriction than others.

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References:

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