

Quantification of Ventilation Heterogeneity from Hyperpolarized ^3He MR Images Using Coefficient of Variation

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Introduction

Heterogeneous constriction of respiratory airways has long been recognized as a primary characteristic of asthma. Its direct effect, ventilation heterogeneity, has been observed and qualitatively described using Hyperpolarized (HP) ^3He MRI, but has not previously been quantified.

Approach

Hyperpolarized (HP) ^3He MR images were acquired before Methacholine (Mch) challenge (preMch), after Mch challenge (postMch), and after deep inspirations (postDI) from healthy and mild-to-moderate asthmatic subjects. The HP ^3He MR images were acquired during breathhold of a 1 L $^3\text{He-N}_2$ mixture, using a Fast GRE pulse sequence, 17° - 18° flip angle, with coronal slice thickness 13 mm, 256×128 matrix, and 46 cm FOV. Experiment protocols were approved by the Institutional Review Board and informed consent was obtained from all volunteer subjects. Coefficients of variation were calculated for a rectangular region of interest around each pixel for all pixels within the lung. The rectangular regions have heights and widths that are approximately 10% of the lung's height and width in the respective coronal slice. Coefficients of variation are defined as the standard deviation as a fraction of the mean, reflecting the relative fluctuation of the variable within the region of interest.

Results and Discussion

Figure 1 depicts the HP ^3He MR images of a healthy subject's mid-coronal slice captured for each phase of the experiment, and the corresponding calculated heterogeneity maps. The homogenous signal distribution of the preMch image is corroborated by the predominantly blue map, indicating low levels of heterogeneity. The development of ventilation heterogeneity postMch is well reflected by the widespread migration of map color towards the warmer end of the spectrum. With the re-opening of airways postDI, much of the ventilation deprived regions recover. With the associated redistribution of inhaled gas, the cooler colors return to much of the heterogeneity map. When applied to an asthmatic subject (data not shown), an elevated heterogeneity is quantified even preMch, and much of the additional postMch heterogeneity does not subside after deep inspirations.

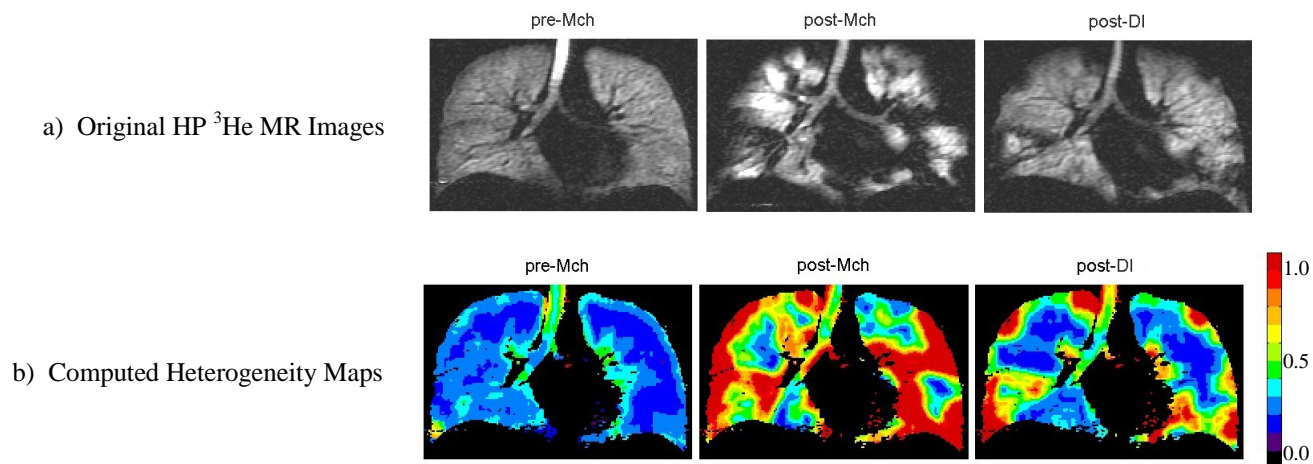


Figure 1. Heterogeneity Maps computed from a Mid-Coronal Slice during Static Breathhold for a Healthy Subject.

Conclusion

The coefficient of variation method is developed and examined as a novel approach for quantifying heterogeneity in HP ^3He MR ventilation images. It portrays local fluctuations in the measured variable over a region of interest of predetermined size. Applied to the ventilation distributions of healthy and asthmatic subjects, the resultant maps illustrate the growth and recession of heterogeneity during each phase of the experiments, and capture key differences between the two subject populations.

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