Optimized diffusion time for long-time-scale Helium-3 diffusion MRI

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Introduction: Hyperpolarized (HP) ^{3}He diffusion MRI measures the degree to which diffusion-driven displacement of inhaled gases molecules is restricted by the walls of the airspaces of the lung, from which information about lung microstructure can be derived (1-4). HP ^{3}He diffusion MRI has been implemented at two diffusion-time regimes: the short-time scale (~ms) and the long-time-scale (~s) (1-4). Long-time-scale diffusion results in ADC values that are roughly an order of magnitude smaller than those for the short-time scale (1-4). Despite the previous success of long-time-scale diffusion MRI using ^{3}He, imaging parameters for this technique were never optimized and as a result research teams have used a variety of different parameters. The purpose of this work is to determine the diffusion time for long-time-scale ^{3}He diffusion MRI which has the best ability to discriminate healthy from COPD subjects.

Methods: A series of global apparent diffusion coefficient (ADC) values (i.e., integrated over the entire lung) were measured at diffusion times ranging from about 0.1 to 2.0 seconds using a stimulated-echo-based method with diffusion sensitization in the anterior-posterior direction (1). The pulse sequence is described in ref. 1. ^{3}He was polarized to ~30% by the collisional spin-exchange technique using a commercial system (Model 9600, MITI). The measurements were obtained from all subjects at breath hold following inhalation of 50 ml ^{3}He mixed with 950 ml N_2. The tag wavelength was 10 mm. Scanner: 1.5T scanner (Sonata, Siemens); Subjects: 29 healthy volunteers (Age: 57±9; 12M, 17F) and 14 subjects with COPD (Age: 65±6; 5M, 9F). The ^{3}He ADC values for each subject and the percentage difference in group mean ADC were calculated.

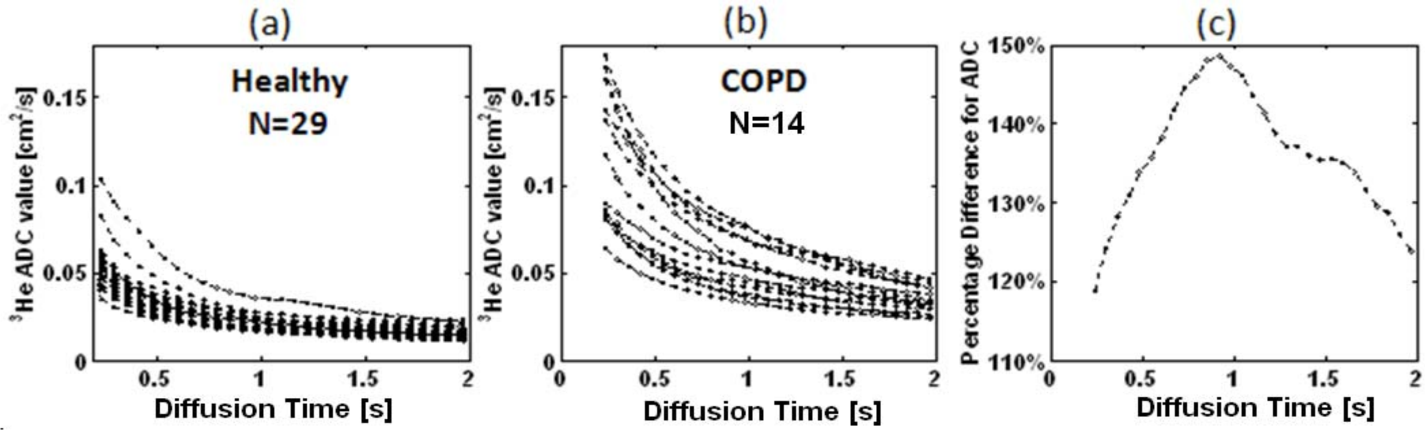

Figure 1. ^{3}He ADC versus diffusion time for (**a**) 29 healthy subjects and (**b**) 14 subjects with COPD. (**c**) Percentage difference of the mean ADC between the COPD and healthy groups versus diffusion time.

Results: According to classical diffusion theory, long-time scale diffusion is expected to be more sensitive to alterations in collateral channel density than short-time scale diffusion since gas atoms have more time in which to explore the lung and potentially pass through a collateral channel. HP ^{3}He long-time scale ADC versus diffusion time curves for 29 healthy subjects and 14 subjects with COPD (Figures 1a, 1b) show a clear separation between these two groups. The percentage difference in group mean ADC versus diffusion time (Figure 1c) has a well-defined maximum at a diffusion time of approximately 1 s, suggesting that for ^{3}He this diffusion time affords the best ability to discriminate COPD subjects from healthy subjects. Furthermore, the percentage difference between the two groups at the long-time scale (110%-150%, Figure 1c) is much greater than that found at the short-time-scale (commonly 20%-100%), which supports the premise that long-time scale diffusion is more sensitive to COPD than short-time scale diffusion.

Conclusion: The global pulse sequence offers a simple method to optimize diffusion time at the long-time-scale for ^{3}He diffusion MRI. These results suggest that, for a tag wavelength of 10 mm, a diffusion time of 1.0 s affords the best ability to discriminate COPD and healthy subjects.

References:

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