Short- and Long-time-scale Hyperpolarized ^{3}He Diffusion MRI in Healthy, Second-hand Smoking, COPD and Asthma Subjects

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Target Audience: Researchers in the hyperpolarized noble-gas MRI field and chest radiologists.

Purpose: Hyperpolarized (HP) ^{3}He diffusion MRI is sensitive to alterations in the microstructure of the lung (1). It has been investigated in two different diffusion-time regimes: short-time-scale (STS) (~ms) (1) and long-time-scale (LTS) (~s) (2,3). Studies suggest that STS ^{3}He diffusion detects information on the alveolar level, while LTS ^{3}He diffusion detects information on the acinar or higher levels. Wang et al. developed a hybrid MRI pulse sequence which can measure both STS and LTS ^{3}He diffusion during a single breath-hold to allow a direct pixel-by-pixel comparison (4). The purpose of this work was to compare STS and LTS ^{3}He apparent diffusion coefficients (ADCs) in healthy subjects, healthy non-smoking subjects with a high exposure to secondhand smoke, patients with COPD, and patients with difficult-to-treat asthma.

Methods: HP ^{3}He diffusion MRI was performed in 24 healthy subjects who never smoked and had low exposure to secondhand smoke (11M, 13F; age: 57.0±7.7 yrs), 34 healthy subjects who never smoked but had high exposure to secondhand smoke (8M, 24F; age: 58.0±8.6 yrs), 15 patients with COPD (7M, 8F; age: 63.6±5.0 yrs) and 14 patients with difficult-to-treat asthma (7M, 7F; age: 57.9±10.0 yrs) using a 1.5T commercial scanner (Sonata, Siemens) modified by the addition of a broadband-imaging package and a flexible chest RF coil (Clinical MR Solutions, Brookfield, WI). ^{3}He was polarized to ~30% by the collisional spin-exchange technique using a commercial system (Model 9600, MITI). MR data was collected during a breath hold lasting no longer than 15 s. A dose of 400-700 ml of ^{3}He was diluted with N_2 to 1/3 of the subject's FVC and inhaled by the subject. Axial multi-slice STS and LTS ADC maps were measured by using a hybrid stimulated-echo based pulse sequence, as described in ref. (4). For STS, diffusion time t = 1 ms, b = 1.6 s/cm^2; for LTS, t = 1.5 s, b = 59.2 s/cm^2. After calculating ADC maps, the mean ADC values at both time scales for each subject were calculated. The group mean ADC was compared between any two groups using one-way ANOVA. A P value of less than 0.05 was used as the criterion for rejecting the null hypothesis of equal means.

Results: The mean ADC values for all groups are presented in Figs. 1 & 2 and in Table 1. Corresponding P values are displayed in Table 2. As we expected, both STS and LTS ADC values were significantly elevated for patients with COPD compared with controls (healthy subjects). For second-hand smokers compared with controls, STS ADC was elevated while LTS ADC was not. However, for asthmatics compared with controls, LTS ADC was elevated while STS ADC was not, Table 2. These findings suggest that STS and LTS ADC are measuring different aspects of the structural changes that occur in the lung with exposure to second-hand smoke and asthma.

Conclusion: STS and LTS ADC appear to be sensitive to different alterations in lung structure.

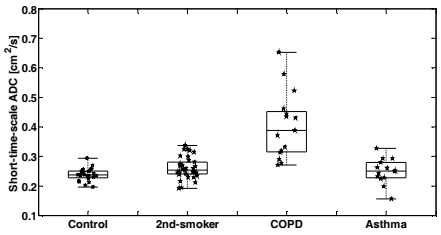

Figure 1. Boxplot of all STS ADC values for the 4 groups.

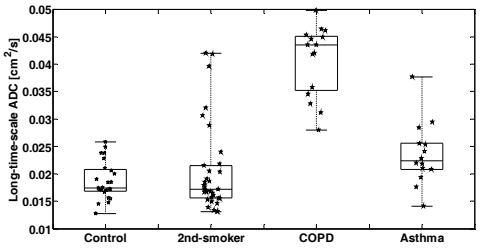

Figure 2. Boxplot of all LTS ADC values for the 4 groups.

Table 1. Group mean ADC. [cm^2/s]

Group	STS ADC	LTS ADC
Control	0.238±0.022	0.0187± 0.0035
2nd smoker	0.261±0.036	0.0204±0.0080
COPD	0.405±0.114	0.0407±0.0065
Asthma	0.249±0.043	0.0236±0.0057

Table 2. The P-value to compare two groups by one-way ANOVA.

	Control		2nd-smoker		COPD		Asthma	
	STS	LTS	STS	LTS	STS	LTS	STS	LTS
Control	1	1	0.01*	0.33$	<0.01	<0.01	0.30	<0.01
2nd-smoker	-	-	1	1	<0.01	<0.01	0.37	0.19
COPD	-	-	-	-	1	1	<0.01	<0.01
Asthma	-	-	-	-	-	-	1	1

*$P \le 0.05$, red; $^{\$}P > 0.05$, black.

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