Passive Tobacco Smoke Exposure Assessed by Long-Time-Scale ^{3}He Diffusion MRI

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Introduction: Cigarette smoking is the primary risk factor for emphysema in the developed nations; however, the effects of passive exposure to smoke on respiratory health are still under debate [1]. Hyperpolarized (HP) ^{3}He diffusion MRI has been used to investigate smoking-related emphysema [2-4]. Long-time-scale apparent diffusion coefficient (ADC) measurements have been shown to be more sensitive to mild emphysematous changes than the standard short-time-scale ADC measurement [4]. The goal of this work was to determine whether long-time-scale ADC measurements can detect the effects second-hand tobacco smoke.

Materials and Methods: HP ^{3}He MRI was performed in twenty-two healthy subjects (10 subjects with low exposure to 2nd-hand smoke, 6 males and 4 females, age range: 47-71 yrs; and 12 subjects with high exposure to 2nd-hand smoke, 3 males and 9 females, age range: 51-79 yrs) and in three subjects with smoking-related mild emphysema (Gold Stage 0-2, 2 males and 1 female, age: 52, 61, 71 yrs) using a 1.5T commercial scanner (Sonata, Siemens). ^{3}He was polarized to ~30% by the collisional spin-exchange technique using a commercial system (Model 9600, MITI). Global long-time-scale diffusion measurements (with diffusion sensitization in the anterior-posterior direction) were obtained for all subjects at breath hold following inhalation of 50 ml HP ^{3}He gas diluted with N_2 to a total volume of 1 liter. A stimulated-echo-based pulse sequence was used with the following parameters: TR, 62 ms; TE_1, 0.5 ms; TE_2, 6 ms; tag wavelength, 10 mm (G_d, 20 mT/m; δ, 0.15 ms); Δ, 48 ms; imaging flip angle, 5°. Global ADC measurements were made at diffusion times ranging from 25 ms to 6 s. To simplify comparisons between groups, only the global ADC values at a specific diffusion time, 1.54 s, are discussed below, but the findings were similar at other diffusion times. For 6 low exposure, 5 high exposure and 3 emphysema subjects, axial multi-slice ADC maps corresponding to both short (1 ms) and long (1.5 s) diffusion times were collected with 400-700 ml ^{3}He, diluted to ~1 liter with N_2, as described in reference 4. Spriometry was performed in all subjects immediately before imaging.

Results: For all healthy subjects combined, the global ADC was poorly correlated with age, weight and FEV_1 (%pred), and was weakly correlated with height and FVC, as shown in Table 1. Male subjects had a slightly larger global ADC (mean: 0.0229 cm^2/s for males, 0.0178 cm^2/s for females, p=0.03). The global ADC values at a diffusion time of 1.54 s for the subjects with high exposure to 2nd-hand smoke (mean ± SD: 0.0204 ± 0.0075 cm^2/s) were more variable than those of the low exposure group (mean ± SD: 0.0193 ± 0.0032 cm^2/s) as seen in Figure 1. Four of the 12 subjects with high exposure, but only 1 of the 10 subjects with low exposure, had an ADC greater than 0.0240 cm^2/s (dashed line in Figure 1), while 8 high-exposure subjects and 3 low-exposure subjects had a global ADC less than 0.0185 cm^2/s (solid line in Figure 1), p=0.01. All subjects with mild emphysema had a global ADC greater than 0.0290 cm^2/s, which is greater than that for all healthy subjects expect for one subject with high exposure. Figure 2 shows both the long and short time scale ADC maps from the high-exposure subject whose data is circled in Fig 1. Elevation of the ADC values is observed in some regions, and is much more apparent in the long-time-scale ADC maps than in the short-time-scale ADC maps.

Discussion: Only a fraction (15-30%) of active smokers develop emphysema (structural damage to the lung) while a larger fraction develop chronic bronchitis (chronic airway inflammation). We found that subjects with high exposure to passive smoke were more likely than low-exposure subjects to have either an increased or decreased long-time-scale ADC. It is possible that a decrease in the long-time-scale ADC reflects airway narrowing, possibly from chronic inflammation, and that an increase in the ADC reflects lung structural damage or subclinical emphysema. Further, the long-time-scale ADC maps appeared to be more sensitive than the short-time-scale ADC maps to regional variations in the lung, as expected [3]. Our results suggest that the long-time-scale ADC measurements may be able to detect the effects of 2nd-hand smoking.

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References: 1. Coultas DB. Thorax 1998; 53:381-387. 2. Fain SB, et al. Radiology 2006; 239:875-883. 3. Woods JC, et al. Magn Reson Med 2004; 51: 1002-1008. 4. Wang C, et al. Magn Reson Med 2006; 56:296-309.

Table 1. Correlation between global ADC values and other subject variables.

Independent variable	Correlation coefficient (r) for ADC at 1.54 s	p-value
Age	0.17	0.444
Height	0.34	0.120
Weight	0.11	0.643
FVC (L)	0.25	0.256
FEV_1 (%pred)	-0.08	0.736

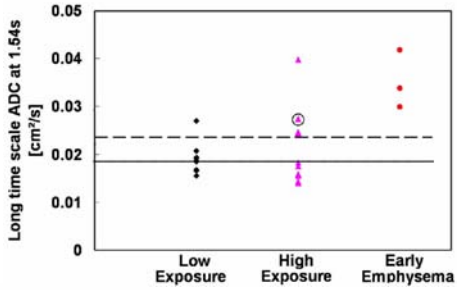

Fig. 1. The global ADC at 1.54 s for the subjects with low exposure and high exposure to 2nd-hand smoke and the subjects with early emphysema.

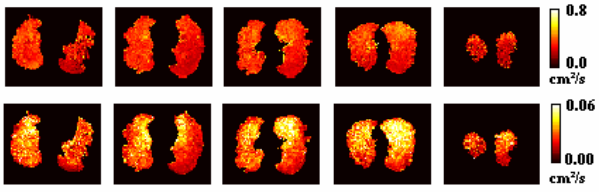

Fig. 2. ADC maps from the subject circled in Fig. 1.
Top row: Short-time-scale ADC maps.
Bottom row: Long-time-scale ADC maps.