

# Elevated short-time-scale hyperpolarized helium-3 diffusion in secondhand smokers

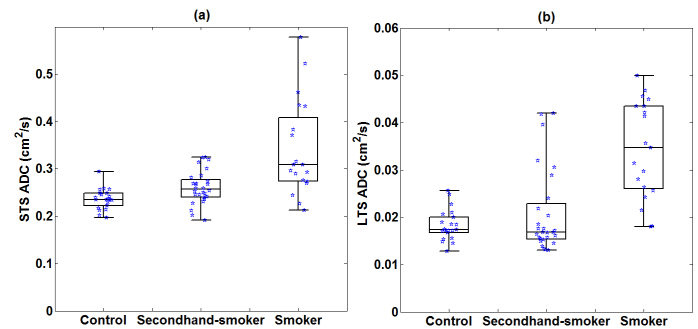
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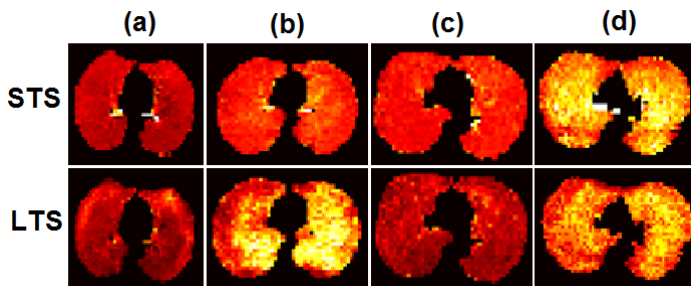
**Introduction:** Cigarette smoking is the primary risk factor for COPD. Although secondhand smoke has been linked with the development of certain cancers and cardiovascular disease, an association with COPD has been difficult to establish. Alterations in alveolar morphology can be assessed with hyperpolarized helium-3 diffusion MRI, on which patients with emphysema have characteristic changes [1,2]. In this study, helium-3 diffusion MRI was used to determine whether similar changes can be detected in healthy individuals who were regularly exposed to secondhand smoke but never smoked themselves.

**Methods:** We studied 3 groups: 19 smokers (age:  $61.1 \pm 7.5$ ; 5M, 14M), 28 secondhand-smokers who had never smoked but had regular exposure to secondhand smoke for ten or more years (age:  $57.4 \pm 8.7$ ; 7M, 21F), and 21 control subjects who had never smoked and had only occasional exposure to secondhand smoke (age:  $56.2 \pm 8.6$ ; 9M, 12F). Imaging was performed on a 1.5T commercial scanner (Sonata, Siemens) modified by the addition of the multi-nuclear imaging package and a flexible RF coil (Clinical MR Solutions, Brookfield, WI). Helium-3 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 helium-3 was diluted with nitrogen to 1/3 of the subject's FVC, and was inhaled by the subject. Axial multi-slice short-time-scale (STS) and long-time-scale (LTS) ADC maps were measured by using a hybrid stimulated-echo-based pulse sequence, as in Refs. 3 and 4. For the short-time-scale, diffusion time  $t = 1.6$  ms,  $b = 1.6$  s/cm<sup>2</sup>; for the long-time-scale,  $t = 1.5$  s,  $b = 59.2$  s/cm<sup>2</sup>. The means of the corresponding ADC maps were calculated and compared.

**Results:** Both STS and LTS ADC maps showed a homogenous distribution for controls with a STS ADC mean of  $0.236 \pm 0.022$  cm<sup>2</sup>/s and a LTS ADC mean of  $0.0183 \pm 0.0033$  cm<sup>2</sup>/s. As expected, for the smokers, both STS and LTS ADC increased, with a STS ADC mean of  $0.342 \pm 0.102$  cm<sup>2</sup>/s (increase of 45%,  $P < 0.001$ ) and a LTS ADC mean of  $0.0343 \pm 0.0103$  cm<sup>2</sup>/s (increase of 87%,  $P < 0.001$ ). Interestingly, for secondhand-smokers, a significant increase was observed for the STS ADC, with a mean of  $0.260 \pm 0.035$  cm<sup>2</sup>/s (increase of 10%,  $P = 0.007$ ), while the increase for the LTS ADC was not significant, with a mean of  $0.0207 \pm 0.0088$  cm<sup>2</sup>/s (increase of 13%,  $P = 0.238$ ), as shown in Fig. 1. For controls, most of their ADC maps showed homogenous distributions, as in Fig. 2a, while many ADC maps showed heterogeneous distributions for smokers, as in Fig. 2d. For secondhand smokers, most showed homogenous STS ADC maps, while 7 subjects showed heterogeneous LTS ADC maps. Two examples for secondhand smokers are illustrated in Figs. 2b and 2c, with Fig. 2b showing a homogenous STS ADC map with increased mean and a heterogeneous LTS ADC map, and Fig. 2c showing a homogenous STS ADC map with increased mean and a homogenous LTS ADC map.



**Figure 1.** Box plots of mean ADC values from controls, secondhand-smokers and smokers for (a) STS and (b) LTS measurements.



**Figure 2.** Representative STS (top) and LTS (bottom) ADC maps from (a) a control, (b) a secondhand smoker with increased STS ADC and increased LTS ADC, (c) a secondhand smoker with increased STS ADC and normal LTS ADC, and (d) a smoker.

**Discussion and Conclusion:** STS and LTS ADC values of smokers were significantly elevated compared to controls and secondhand-smokers ( $P < 0.001$  for both). One-way ANOVA indicated that the mean STS ADC values from secondhand-smokers was significantly elevated compared with that of the control group (increase of 10%,  $P = 0.007$ ) while not for the LTS ADC.

There are many possible reasons why the LTS ADC did not show a significant increase for secondhand smokers. Noisier ADC maps and different ventilation levels may play a role. The STS and LTS ADC are investigating different lung structures, which may vary for exposure to secondhand smoke. We found that 7 subjects had both increased STS and LTS ADC, as in Fig. 2b, while 11 secondhand-smokers had increased STS ADC while their LTS ADC remained normal, as in Fig. 2c. We thus suspect that STS and LTS

ADC are measuring different structural progression due to exposure to secondhand smoke.

## References:

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