Long-time-scale hyperpolarized Helium-3 diffusion MRI: global versus regional measurements

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Introduction: Hyperpolarized 3He (HHe) diffusion MRI is sensitive to lung microstructural changes and has been investigated in both short-time scale (STS: ~ms) and long-time scale (LTS: ~s). Recent studies suggested that LTS HHe diffusion is more sensitive to early emphysematous changes [1-3]. However, LTS HHe diffusion MRI suffers from requirements of higher SNR because of its stimulated echo basis. Despite lack of regional information, global (i.e., integrated over the entire lung) ADC measurements should be sensitive to early emphysematous changes as well. In this study, we will measure global and regional LTS HHe diffusion in healthy subjects and smokers, and then determine whether global ADC can be a substitute for the mean of regional ADC maps to distinguish smokers from controls.

Methods: Two groups of subjects were recruited from the local community by advertisement: healthy subjects who had never smoked and only had occasional exposure to secondhand smoke (control group) and subjects who smoked actively or were prior smokers (smoker group). The smoker group consisted of current and former smokers with a self-reported smoking history of at least 6 pack-years. Exclusion criteria for the control groups were a personal history of active smoking, abnormal spirometry defined as a forced expiratory volume in 1 second (FEV1) < 80% predicted or FEV1/FVC (forced expiratory vital capacity) < 70, a history of chronic lung disease, symptoms of asthma or other lung disease, allergies, or a history of pneumonia requiring hospitalization. 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 (CMRS, Brookfield, WI). 3He was polarized to ~30% by the collisional spin-exchange technique using a commercial system (Model 9600, MITI). MR data was collected during breath holds lasting no longer than 15 s. A series of global ADC values were measured at diffusion times ranging from about 0.1 to 5.0 seconds using a global stimulated-echo-based method with diffusion sensitization in the anterior-posterior direction [2]. The global pulse sequence is described in ref. 2. Here, only 50 ml of HHe was used. For next dose, axial multi-sliced LTS HHe ADC maps were measured at a diffusion time of 1.5 s with a b value of 59.2 s/cm² by using a hybrid regional stimulated-echo based pulse sequence, as in Ref. 3. To achieve enough SNR, 400-700 ml HHe was used. The means of the ADC maps were calculated and compared with the global ADC at 1.47 s with a b value of 58.0 s/cm².

Results: A total of 38 subjects were enrolled in this study, including 19 controls and 19 smokers. The smokers reported an average smoking history of 47 ± 27 pack years. There was no significant differences in age, gender, height, weight or BMI between the two groups, as in Table 1. The box plots for FEV1%predicted, the global ADC at 1.47 s and the mean of the ADC maps at 1.5 s were displayed in Figs 1a, 1b and 1c. As expected, for smokers compared with the control, FEV1%predicted decreased for 24.4% (P < 0.01), and the global ADC increased 107.1% (P < 0.01) while the group mean of regional ADC maps increased 93.2% (P < 0.01). Global ADC strongly correlated with mean of regional ADC maps, r=0.96, P<0.01. Fig. 2.

Discussion and Conclusion: As expected, both global ADC and mean of regional ADC maps distinguished smokers and controls very well. And global ADC nicely correlates with mean of the ADC maps despite their different diffusion-encoding directions and slightly different diffusion times. Almost all research teams were measuring regional ADC maps when using HHe diffusion MRI, the mean of the ADC maps was the mostly commonly used and most important parameter. Here, we showed that the global ADC can nicely work as a substitute for the mean of the regional ADC maps while keeping the high sensitivity of HHe diffusion MRI technique. Considering the high cost of 3He gas, the global ADC measurements may be used to scan high-risk subjects with a small dose of expensive 3He gas.

References:

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Table 1. Demographic, spirometric and ADC data for all subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>FEV1(%pred)</th>
<th>FEV1/FVC (%)</th>
<th>Global ADC (cm²/s)</th>
<th>Mean of regional ADC (cm²/s)</th>
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<tbody>
<tr>
<td>Control</td>
<td>57.1 ± 8.6</td>
<td>8M, 11F</td>
<td>97 ± 9</td>
<td>80 ± 4</td>
<td>0.0168 ± 0.0026</td>
<td>0.0177 ± 0.0028</td>
</tr>
<tr>
<td>Smoker</td>
<td>61.1 ± 7.5</td>
<td>5M,14F</td>
<td>73 ± 23</td>
<td>63 ± 16</td>
<td>0.0348 ± 0.0135</td>
<td>0.0342 ± 0.0103</td>
</tr>
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Figure 1. The boxplots for a) FEV1%predicted; b) Global ADC at 1.47s; and c) mean of the regional ADC maps at 1.5 s for the control and smoker group.

Figure 2. Global ADC vs mean of regional ADC maps.