Long-time-scale Hyperpolarized ^{3}He Diffusion MRI is More Sensitive than Short-time-scale ^{3}He Diffusion MRI for Detecting COPD

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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 emphysematous changes from the breakdown of alveolar walls and associated structures (1). It has been investigated at two different time scales: short-time-scale (STS) (on the order of ms) (1) and long-time-scale (LTS) (on the order of seconds) (2,3). Studies suggest that STS ^{3}He diffusion detects information at the alveolar level, while LTS ^{3}He diffusion detects information at the acinar or higher levels. Some researchers hypothesized that LTS ^{3}He diffusion is more sensitive to early emphysema than STS ^{3}He diffusion (2,3). A hybrid MRI pulse sequence developed by Wang et al measures 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 the ability of these two techniques to distinguish healthy subjects from patients with COPD.

Methods: HP ^{3}He diffusion MRI was performed in 24 healthy subjects who never smoked (11M, 13F; age: 57.0 ± 7.7 yrs; FEV_1%predicted: 100% ± 11%) and 15 patients with COPD (7M, 8F; age: 63.6 ± 5.0 yrs; FEV_1%predicted: 66% ± 20%) using a 1.5T commercial scanner (Sonata, Siemens) modified by the addition of a broadband-imaging package and a flexible 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. The ADC data from each pixel of all subjects in the same group were put together to calculate histograms. A receiver operating characteristic (ROC) analysis was performed to find the optimum threshold, and the specificity and sensitivity for each method.

Results: The ADC maps were homogenous for most healthy subjects with mean ADC values of 0.238 ± 0.022 cm^2/s for STS and 0.0187 ± 0.0035 cm^2/s for LTS. As expected, for patients with COPD, both STS and LTS ADC increased, with the STS ADC mean of 0.405 ± 0.114 cm^2/s (increase of 70.0%, P<0.001) and the LTS ADC mean of 0.0407 ± 0.0065 cm^2/s (increase of 117.4%, P<0.001). Figure 1 presents representative STS and LTS ADC maps from a healthy subject and a patient with COPD.

Putting all of the pixel-wise ADC data from each subject together shows a clustering of the ADC values for healthy subjects and a markedly increased number of elevated ADC values in COPD patients, Fig. 2a. The greater separation of the histogram peaks for the LTS data (Fig. 2c vs. 2b) suggests that the LTS ADC may be more sensitive than the STS ADC to the changes of COPD. Table 1 presents the results of the ROC analysis. The LTS ADC had a greater area under the ROC curve (0.920) than the STS ADC (0.849); again suggesting that LTS ADC is more sensitive to emphysema than STS ADC.

Conclusion: The LTS ^{3}He ADC appears to be more sensitive to the changes in the lung of COPD than the STS ^{3}He ADC.

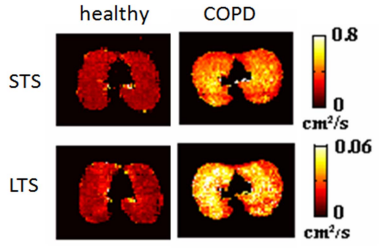

Figure 1. Representative ADC maps from a healthy subject and a patient with COPD.

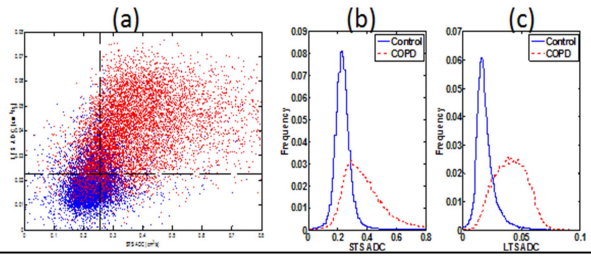

Figure 2. (a) Scatter map of all ADC data; (b) histogram of STS ADC values; and (c) histogram of LTS ADC values.

Table 1. Results of ROC analysis

	Area under ROC	Optimum threshold (cm^2/s)	Sensitivity	Specificity
STS ADC	0.849	0.244	0.782	0.782
LTS ADC	0.920	0.0192	0.852	0.852

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