The Apparent Diffusion Coefficient of Xe-129 in the Lung: Preliminary Human Results

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Introduction: The apparent diffusion coefficient (ADC) of hyperpolarized He-3 in the lung has been measured in healthy subjects and subjects with emphysema [1,2]. Initial evidence indicates that He-3 ADC values increase in proportion to the degree of microstructural damage, suggesting that He-3 diffusion imaging may be a sensitive technique for detecting and evaluating structural derangements of the lung. The *other* hyperpolarized gas, Xe-129, has a self-diffusion constant that is roughly 30 times smaller than that for He-3. Thus, compared to He-3, the length scales probed by Xe-129 are expected to be smaller, and perhaps diffusion imaging with Xe-129 can provide unique information regarding disease-induced structural changes in the lung. Nonetheless, compared to He-3, imaging with Xe-129 has been slower to develop, particularly for human applications. Recent improvements in the polarization levels for liter quantities of Xe-129 have made it practical to perform Xe-129 diffusion imaging in the human lung with spatial resolution similar to that achieved with He-3. We report here preliminary measurements of the Xe-129 ADC in the human lung.

Methods: Hyperpolarized Xe-129 MRI was performed in two healthy subjects (ages 22, 35) using a 1.5T whole-body imager (Magnetom Sonata; Siemens Medical Solutions, Malvern, PA) and a prototype flexible Xe-129 chest RF coil (IGC Medical Advances, Milwaukee, WI). The studies were performed using a protocol approved by our Institutional Review Board; informed written consent was obtained from each subject. Xenon (enriched to 85% Xe-129) was polarized by collisional spin exchange using a modified prototype system (Model 9600 Xenon Polarizer; Magnetic Imaging Technologies Incorporated, Durham NC). By optimizing the sublimation process, which can be a source of substantial polarization loss, and increasing the laser power we now consistently achieve polarization levels of 10-15% for 500-600 ml of hyperpolarized gas. For each study, 500-600 ml of polarized xenon gas was transferred to a Tedlar plastic bag (Jensen Inert Products, Coral Springs, FL). Medical grade N_2 was then added to yield a total volume of 1 liter. The bag was then transported to the MR scanner and inhaled by the subject.

Contiguous coronal Xe-129 diffusion images were obtained at 30-mm intervals covering the whole lung volume using a FLASH-based pulse sequence (TR/TE, 16/11 ms; FA, 10°; matrix, 40 x 64; FOV, 34 x 42 cm; thickness, 30 mm; b-values, 0 and 10 s/cm^2) with diffusion weighting in the anterior-to-posterior direction. The means and standard deviations of ADC values for each section and for the sum of all sections were calculated.

Results: The means and standard deviations of Xe-129 ADC values for each section are presented in Table 1. The global (i.e., summed over all sections) ADC values for the two subjects were 0.039 ± 0.016 cm^2/s and 0.036 ± 0.014 cm^2/s. Figure 1 shows the ventilation (b=0) images and ADC maps for subject 2. Aside from the lower spatial resolution, the ventilation images appeared qualitatively similar to those obtained from healthy volunteers using He-3; the signal from xenon was in general uniformly distributed throughout the lung parenchyma. Similarly, as expected, the ADC maps showed fairly uniform values throughout the lungs.

Table 1. Mean ± standard deviation of the ADC values [cm^2/s] calculated for each section in the two subjects.

Section #	Subject 1	Subject 2
1	0.043 ± 0.020	0.039 ± 0.018
2	0.041 ± 0.015	0.039 ± 0.014
3	0.039 ± 0.014	0.036 ± 0.012
4	0.038 ± 0.015	0.035 ± 0.014
5	0.036 ± 0.015	0.036 ± 0.014
6	0.037 ± 0.022	0.036 ± 0.015

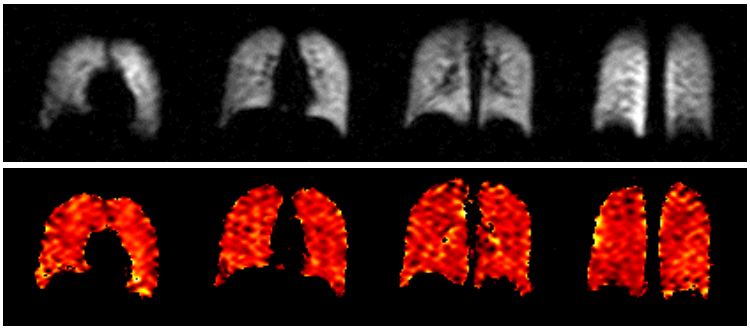

Fig. 1. Coronal Xe-129 ventilation (b = 0) and ADC maps from subject 2. The central 4 of 6 sections are shown.

Discussion: These preliminary measurements suggest that the ADC values for Xe-129 in the healthy human lung are 5-6 times smaller than those for He-3. The mean ADC of 0.04 cm^2/s is approximately twice that measured in the lung of a healthy guinea pig [3]. From estimated values for the free diffusion constants of He-3 and Xe-129 in air (0.86 and 0.14 cm^2/s, respectively [3]), the ratios of the free-diffusion values in air to the respective ADCs in the healthy human lung are roughly 4 for both gases. We plan to perform Xe-129 ADC measurements in additional healthy subjects, and then investigate the dependence of Xe-129 ADC values on the severity of lung disease, particularly emphysema, compared to the changes seen with He-3 diffusion imaging and high-resolution CT.

References: 1. Saam BT et al. Magn Reson Med 2000; 44:174-179. 2. Salerno et al. Radiology 2002; 222:252-260. 3. Chen XJ et al. Magn Reson Med 2000; 42:721-728.

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