# Measurement of the diffusion of hyperpolarized $^{129}$Xe in human lungs over short and long time scales during one breath hold

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**Introduction:** Hyperpolarized (HP) noble gas ($^3$He and $^{129}$Xe) diffusion MRI, which can be used to non-invasively assess the lung microstructure, has been shown to detect the early microstructural changes in emphysema [1,2]. Research on $^{129}$Xe diffusion MRI has significantly lagged behind that for $^3$He because of historically low polarization levels achieved for $^{129}$Xe. In recent years, higher polarization levels for $^{129}$Xe have become available, which greatly enhances its possible clinical applications [3]. The purpose of this study is to investigate whether current signal-to-noise ratio (SNR) is sufficient to perform regional $^{129}$Xe diffusion measurements, and to acquire regional $^{129}$Xe diffusion maps in human lungs, measured over both short- and long-time-scales and with identical spatial registrations, in one breath hold.

**Methods:** HP $^{129}$Xe ADC maps can be obtained for the short-time-scale (~ ms) with the interleaved-GRE-based-method that is commonly used for HP $^3$He diffusion measurements. Such a short-time-scale-measurement thus can be appended before a stimulated-echo-based, long-time-scale (~0.5-5s) diffusion pulse sequence [4] so that ADC maps corresponding to two distinct diffusion-times, but with the same spatial registration, can be acquired in one-breath-hold.

$^{129}$Xe diffusion MRI was performed in 5 subjects [2 healthy, 1 cystic fibrosis (CF), 1 asthma and 1 sickle cell disease (SCD)] using a 1.5T commercial scanner (Avanto, Siemens) and a flexible chest RF coil (Clinical MR Solutions). $^{129}$Xe was polarized to ~10-40% by the collisional spin exchange technique using a prototype polarization system (Xemed, LLC). Air and $O_2$ were mixed with about 500 ml HP $^{129}$Xe, which was then inhaled by the subjects. b values of 0 and 6 s/cm$^2$, and a diffusion time ($t_d$) of 2 ms, were used for the GRE-based-technique. Parameters for the stimulated-echo-based technique included b = 238 s/cm$^2$, tag wavelength = 5 mm and $t_d$ = 1.5 s. Coronal projection imaging was performed in 1 healthy subject and the CF subject. Three axial ADC maps were acquired in the other subjects.

**Results:** The demographic data and ADC measurements for all subjects are listed in the table below. Example ADC maps from each subject are shown in Fig 1. The short-time-scale $^{129}$Xe ADC was in the range of 0.02 – 0.05 cm$^2$/s, about 10-20% of previously reported values for $^3$He ADC [1,4], while the long-time-scale $^{129}$Xe ADC was in the range of 0.003 – 0.10 cm$^2$/s, about 5-10% of previously reported values for $^3$He ADC [2.4].

Table 1. The demographic and ADC data for all subjects.

| Subject number | Age (yrs) | Gender | FEV1 (%pred) | Indication | Imaging direction | Short-time-scale (~ ms) | | | Long-time-scale (~ s) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | SNR | Mean ADC¶ | STD ADC¶ | SNR | Mean ADC¶ | STD ADC¶ |
| 1 | 25 | F | 85 | Healthy | Coronal | 39 | 0.033 | 0.013 | 70 | 0.0070 | 0.0023 |
| 2 | 21 | F | 103 | Healthy | Axial | 44 | 0.040 | 0.016 | 122 | 0.0085 | 0.0022 |
| 3 | 19 | M | 120 | CF | Coronal | 39 | 0.029 | 0.017 | 100 | 0.0086 | 0.0030 |
| 4 | 18 | F | 82 | SCD | Axial | 20 | 0.040 | 0.023 | 35 | 0.0044 | 0.0017 |
| 5 | 67 | M | 36 | Asthma | Axial | 16 | 0.046 | 0.024 | 31 | 0.0060 | 0.0019 |

¶: Unit: (cm$^2$/s);

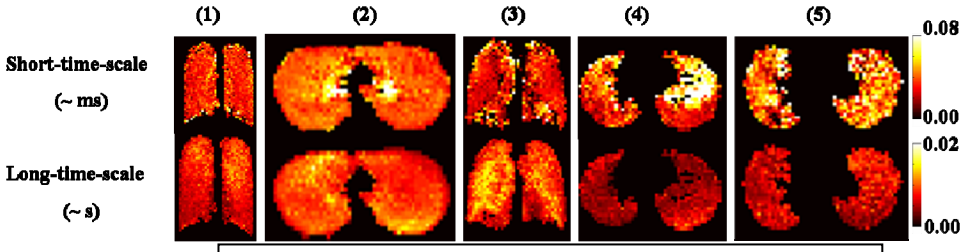


Figure 1. Example ADC maps from each subject. Unit is cm$^2$/s.

**Conclusion:** Co-registered ADC maps of $^{129}$Xe at two time scales were acquired successfully in a single breath hold in 5 human subjects. The measured $^{129}$Xe ADC values were about 10% of the previously reported $^3$He ADC at both time scales, which is similar to but slightly lower than values expected on the basis of the difference in diffusivity alone (the diffusivity of $^{129}$Xe in air is 16% of that for $^3$He). It is possible that differences in other physical properties of the gases (xenon is 20 times more soluble in human tissue and 2 times more viscous than helium) secondarily contribute to the difference in $^{129}$Xe and $^3$He ADC. The current SNR of $^{129}$Xe is sufficient to use diffusion MRI to investigate the lung microstructure, and $^{129}$Xe diffusion MRI can be performed in patients with cystic fibrosis, sickle cell disease and asthma.

**References:** 1. Chen XJ, et al. Proc Natl Acad Sci 2000; 97:11478-81. 2. Wang C, et al. Magn Reson Med 2006; 56:296-309. 3. Hersman FW, et al. Acad Radiol 2008; 15(6):683-692. 4. Wang C, et al. J Magn Reson Imaging 2008;28(1):80-88.

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