# Human Pulmonary Gas State Imaging at 0.2T with Hyperpolarized 129Xe

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## Introduction

The full potential of hyperpolarized $^{129}$Xe MRI has been hampered by not having a polarizer that produces polarization levels similar to that available for $^{3}$He. In addition, it has long been recognized that susceptibility-induced dephasing in the lung will be less at low field yet the vast majority of hyperpolarized MRI research has been done at 1.5T. Here we present the first human gas-state results at a low field of 0.2T using the Univ of NH $^{129}$Xe polarizer [1], which typically produces 1.2L/hr @ 45% polarization.

## Methods

Both FDA IND and local IRB approval were obtained to perform $^{129}$Xe breath-hold MRI in healthy human subjects. The protocol requires that the overall concentration of xenon not exceed 35% and that the inhaled gas mixture contain at least 21% oxygen. Breath-hold times were ≤ 20s. ECG, $SpO_2$, blood pressure, heart rate and respiratory rate were measured before and after each experiment and $SpO_2$ was monitored in the scanner as well. Either a physician or RN was present for each breath.

A Tecmag Apollo research spectrometer was interfaced to a GE Profile IV 0.2T magnet and used to control its gradient coils and gradient power amplifiers. A completely separate RF system was constructed including a whole body RF coil, manufactured by Mirtech, Inc. was used for all human experiments. This coil has a Q of ~300 and is only loaded by 4% with a human body.

A number of different pulse sequences were performed including ventilation maps, ADC maps, and dynamic ventilation movies. Normal isotopic abundance (26%) $^{129}$Xe was used for these gas-state images. Standard gradient echo methods were used for all studies. For ADC maps, three b values were measured: 0, 3.88 and 9.92 cm$^2$/s. For all studies, experiments with two different volumes, 1L and 1.8L of 26% $^{129}$Xe were performed. For dynamic studies, several flip angles were used as in $^{3}$He studies to accentuate either the bronchial tree, i.e. early in the inspirate (large flip angles ~10 – 13$^o$) versus the acinar region, i.e. late in the inspiration (smaller flip angles ~4$^o$).

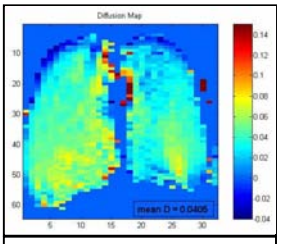

Figure 2. ADC map. $\overline{ADC} = 0.0405 cm^2/s$

## Results

The UNH polarizer was remarkably reliable and robust with no "down time" over the past 6 months. Typical operation allowed an experiment every 75 minutes. An example of multi-slice ventilation images is shown in Fig. 1. Here 1L of 26% 129Xe was inhaled and image SNR ranges from ~10-25. Several ADC experiments with $\Delta$=6ms were performed and ADC projection maps obtained. Mean values of ADC for two different lung volumes (RV + 1.3L and RV + 2.94L) were 0.0385 and 0.0405 cm$^2$/s respectively, which is in good agreement with previously reported results at 1.5T [2]. Phantom measurements were performed on a cell with known pressure of xenon gas and the expected free diffusion constant of xenon for that pressure agreed within 2% of the literature value. For dynamic studies, sequential images were acquired and a moving window incremented by one line of k-space was used to reconstruct each frame. Fig. 3 is a frame from the dynamic series.

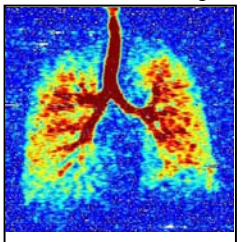

Figure 3. Example of dynamic movie frame.

## Discussion and Conclusions

Ventilation multi-slice images were consistently obtained from standard gradient echo methods and 26% $^{129}$Xe in a single breath-hold.

ADC maps: Projection maps for ADC were obtained with 26% $^{129}$Xe. Estimating the starting lung volume and knowing the composition of the gases inhaled, the diffusivity of the gas mixture in the lung was estimated. For $\Delta$=6ms, the estimated mean free diffusion length for an unrestricted geometry, $L_D$, is ~240um for both diffusion experiments. The ratio of $L_D$ to the estimated average alveolar diameter at each lung volume was then calculated. This ratio is 1.0 and 0.85 for the two ADC experiments indicating that although we are still in the "tortuosity" limit of diffusion [3], we are still probing distances less than one alveolar diameter.

Dynamic imaging: A cubic spline interpolation using the k=0 lines from each image as input was used to estimate the value for time points between the k=0 lines. This fit was used to scale the signal intensity of all k lines for each frame to be the same but allowing the intensity for each frame to smoothly change and follow the fitted intensity vs time. This removed a pulsating intensity that occurred when the k-space window moved to a new k=0 line.

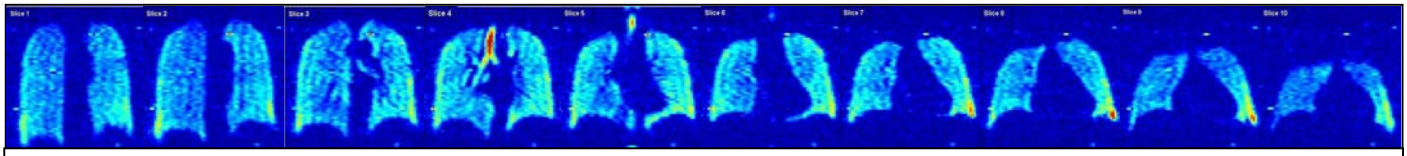

Figure 1. 2D multi-slice gradient echo images from a breath of 1L 26% 129Xe. Slice thickness=12mm, gap 2mm, FOV=300mm, matrix 64x32. TE=11ms, TR=30ms, $\alpha$=4$^o$, acquisition readout bandwidth = 5.9kHz.

**References**

1. I. Ruset, F.W. Hersman, ISMRM p1839 (2005).
2. J.P. Mugler et al, ISMRM p769 (2004).
3. R.W. Mair et al. Phys Rev Lett 83 #16:3324-3327 (1999).

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