Human Pulmonary Diffusion Weighted Imaging at 0.2T with Hyperpolarized 129Xe

A. Sindile[1], I. Muradian[1,2], M. Hrovat[3], C. Johnson[1,2], F. W. Hersman[1], and S. Patz[2]

[1]Department of Physics, University of New Hampshire, Durham, NH, United States, [2]Department of Radiology, Brigham and Women's Hospital, Boston, MA, United States, [3]Mirtech, Inc., Brockton, MA, United States

Introduction:

The Univ of NH ^{129}Xe polarizer [1], which typically produces 1.2L/hr @ 55% polarization, has allowed our collaboration to benefit from the full potential of hyperpolarized ^{129}Xe imaging. At the same time, the low field 0.2T magnet diminishes susceptibility-induced dephasing in the lung. In the past [2], we presented human pulmonary diffusion weighted images. At that time it was noticed that there is a sizeable apex to base ADC (Apparent Diffusion Coefficient) variation. This is in contrast to ^{3}He [3], which shows a very homogeneous ADC distribution inside the human lungs. To determine whether these differences are due to regional variations in Xe dilution, which would affect diffusitivity, we measured ADC as a function of a number of exhaling/rebreathing cycles (breaths). The results of our initial investigations into these differences are presented in this abstract.

Methods:

Our operational protocol requires that the overall concentration of pulmonary xenon does not exceed 35% and that the inhaled gas mixture contains at least 21% oxygen. ECG, SpO_2, blood pressure, heart rate and respiratory rate were monitored before and after each experiment and SpO_2 was also monitored during the MRI experiment. Either a physician or RN was present for each experiment. A Tecmag Apollo research spectrometer was interfaced to a GE Profile IV 0.2T magnet to provide broadband operation and research flexibility. A completely separate RF system including a whole body RF coil was used for all human experiments.

A multiple breath protocol was implemented whereby diffusion weighted images were taken after one, two and three breaths. The subject was instructed to exhale to near RV before inhaling the first breath of ~1.3 liters of an enriched hyperpolarized $^{129}Xe/O_2$ /Air mixture (~FRC). For the second and third breaths, the subject exhaled completely into a plastic bag through ~1/2" diameter tubing and re-inhaled the contents of the bag. The diffusion weighted sequence consisted of a gradient echo sequence (TE=14ms), small flip angles (~5.5deg) with each line of k-space repeated in an interleaved manner for different "b" values. We utilized four "b" values of 0, 3.88, 5.58, and 9.92 s/cm^2. Total acquisition time was typically <3s. Diffusion weighted images were divided into left and right lungs separately and the mean ADC values from R/L were plotted as a function of S/I position in the lungs, from apex to base.

Results:

Figure 1 shows a ^{129}Xe ADC image of the lung for a single breath. Notice that there is significant heterogeneity with higher ADC values observed toward the base. Figure 2 shows the left and right apex to base ADC variation after the first breath (inhalation of the Xe/O_2/Air mixture) while Figures 3 and 4 show the ADC variation after the second and third breaths respectively. It is clear the initial slopes we see from apex to base get smaller (flatter) with gas rebreathing. While the right lung seems to be more homogeneous after just two breaths, the left lung (whose ADC apex to base slope was steeper initially) further improves from the second to third breath.

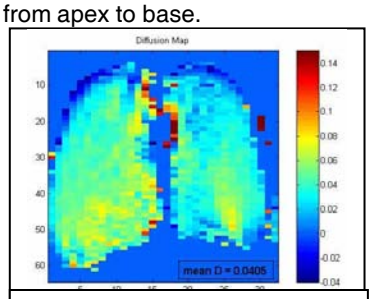

Figure 1. ADC map.
$\overline{ADC} = 0.0405 cm^2/s$

Discussion:

At FRC the apex of the lung is more vacuous then the base and it is also less compliant. Thus, Xe is expected to be at lower concentrations toward the apex relative to the base after the first breath. Lower concentrations of Xe should translate [4] into higher ADC values at the apex. As restriction (larger boundaries) is expected to be less toward the apex, this would also produce higher ADC values. In this study as well as our past work [2], we have observed the exact opposite. Figure 1 shows higher ADC values at the base in both lungs. Figures 3 and 4 demonstrate a reduction in apex to base variation upon rebreathing. Since rebreathing would homogenize Xe concentration throughout the lung, this suggests that the apex/base variation is related to Xe dilution.

Conclusion:

Unlike hyperpolarized ^{3}He inhalations, which achieve a high degree of gas mixture homogeneity due to the higher diffusion constant, hyperpolarized ^{129}Xe requires additional precautions to assure gas mixture homogeneity. We conclude that a homogeneous concentration of Xe inside the lungs is necessary to allow the use of ADC values as a reproducible measure of lung physiology and structure. The disparity of the base/apex variation between the right and left lungs is also unexpected and worthy of further study.

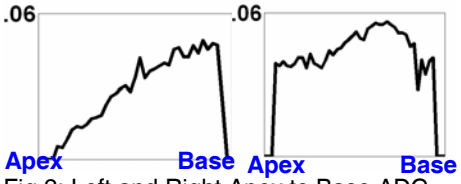

Fig.2: Left and Right Apex to Base ADC after 1 Breath. Note the steep slopes.

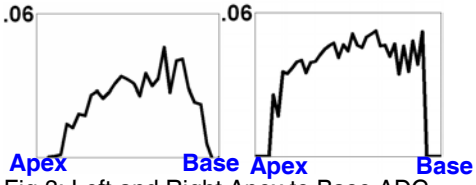

Fig.3: Left and Right Apex to Base ADC after 2 Breaths. Slopes start decreasing.

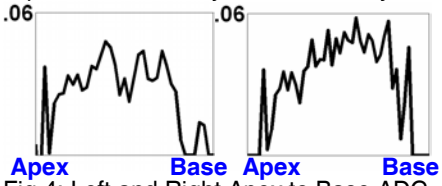

Fig.4: Left and Right Apex to Base ADC after 3 Breaths. ADCs are much flatter.

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