

Oxygen Partial Pressure and Uptake Rate in the Lung with Hyperpolarized ^{129}Xe MRI: Preliminary Results

M. Dabaghyan¹, I. M. Dregely², I. Muradyan¹, M. I. Hrovat³, H. Hatabu¹, J. P. Butler⁴, and S. Patz¹

¹Department of Radiology, Brigham and Women's Hospital, Boston, MA, United States, ²Department of Physics, University of New Hampshire, Durham, NH, United States, ³Mirtech, Inc, Brockton, MA, United States, ⁴Department of Environmental Health, Harvard School of Public Health, Boston, MA, United States

Introduction

Hyperpolarized (HP) ^3He MRI has been extensively used to measure partial pressure of the oxygen and its uptake rate by the blood (1,2). The underlying principle for these measurements is the dependence of T_1 of the HP gases on the presence of paramagnetic oxygen molecules. The same principle holds for ^{129}Xe , however with an added complication – xenon also dissolves into the gas-blood barrier and blood, thus intensifying the depletion of the gas phase signal. To our knowledge there has been only one report of a parameter, equivalent to oxygen partial pressure using HP ^{129}Xe ($p\text{O}_2$ equivalent because no correction was made for Xe uptake by the blood) (3,4). Here we present 3D measurement of $p\text{O}_2$ and RO_2 with HP xenon.

Materials and Methods

Experiments were done in accordance with approved IRB protocol. All subjects signed a consent form prior to their participation. All experiments were performed on a

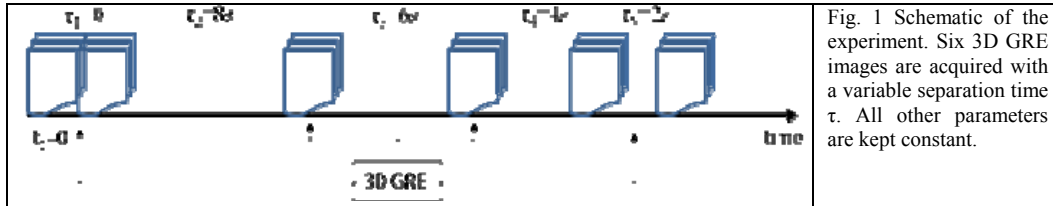


Fig. 1 Schematic of the experiment. Six 3D GRE images are acquired with a variable separation time τ . All other parameters are kept constant.

Siemens Tim Trio Scanner at Martinos Center for Biomedical Imaging, Charlestown, MA. A 3D gradient echo sequence was used to acquire 6 consecutive images during a breath-hold with variable delay times (see Figure 1). The measurements were performed using a 32-channel Xe coil (5). The flip angle was kept the same in all images. The sequence parameters were as follows:

TE/TR = 1.76/3.7 ms, matrix size 16x16x8 with 2 cm resolution in all directions, flip angle = 4 degrees. The delay times were set to: 0,8,6,4, and 2 sec. Each image took 450 ms, with the full experiment lasting less than 22.5s. During the experiments, subjects were asked to inhale 640mL of HP 85% enriched ^{129}Xe and 100% O_2 mixture and hold their breath during the run.

Measured HP gas signal intensity can be written as $S_n(t) = S_1 \cdot \cos^{(n-1)N}(\alpha) \cdot e^{-\frac{t}{T_1}}$, where S_1 is the initial signal, n is the number of acquired images, and N – number of applied RF pulses per image. Then, upon using the T_1 dependence on oxygen partial pressure $\frac{1}{T_1(t)} = \frac{p(t)}{\xi} = \frac{(p_0 - R_{\text{O}_2} t)}{\xi}$, where ξ is an oxygen enhancement factor (2.88e3 for 3T @ body temperature) (3), one can obtain initial oxygen partial pressure and its blood uptake rate (1-4):

$$S_n(t) = S_1 \cdot \cos^{(n-1)N}(\alpha) \cdot e^{-\frac{1}{\xi}(p_0 - R_{\text{O}_2} t)}$$

The data were read into and analyzed in Matlab. The data from each coil was Fourier Transformed and then combined using sum of squares method (ref) to obtain final images. The time dependent data from each pixel was fit to the functional form above.

Results

Figure 2 shows an example of the results from one of the slices. In Fig.2a flip angle distribution through a slice is presented for 3 sample slices, in 2b – initial partial pressure of the oxygen, 2c – rate of oxygen uptake by the blood for the same slices. The global mean values for the parameters were calculated: 3.7 ± 0.02 degrees, 159.9 ± 5.2 mbar and 0.99 ± 0.2 mbar/s for flip angle, initial partial pressure and uptake rate of the oxygen. Figure 3 a-c show histograms of the flip angle, $p\text{O}_2$ and RO_2 , calculated from the whole set.

Discussion

Here we report on measurements of flip angle, oxygen partial pressure and its uptake rate by the blood. The global average of $p\text{O}_2$ is 159.9 mbar, which corresponds to 120 mm Hg. This is slightly higher than expected in a normal healthy volunteer. For oxygen uptake rate, we measured an average value of 0.99 mbar/s. These numbers are in good agreement with those previously reported from the ^3He studies (1,2).

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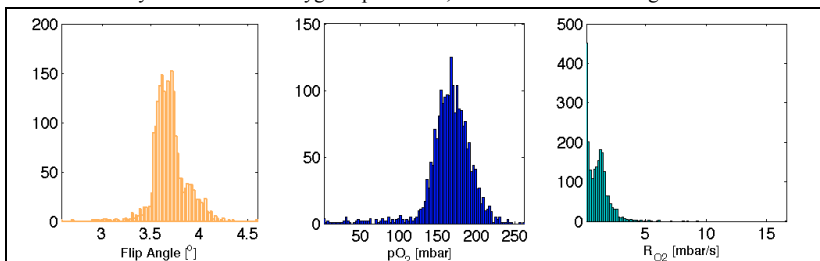
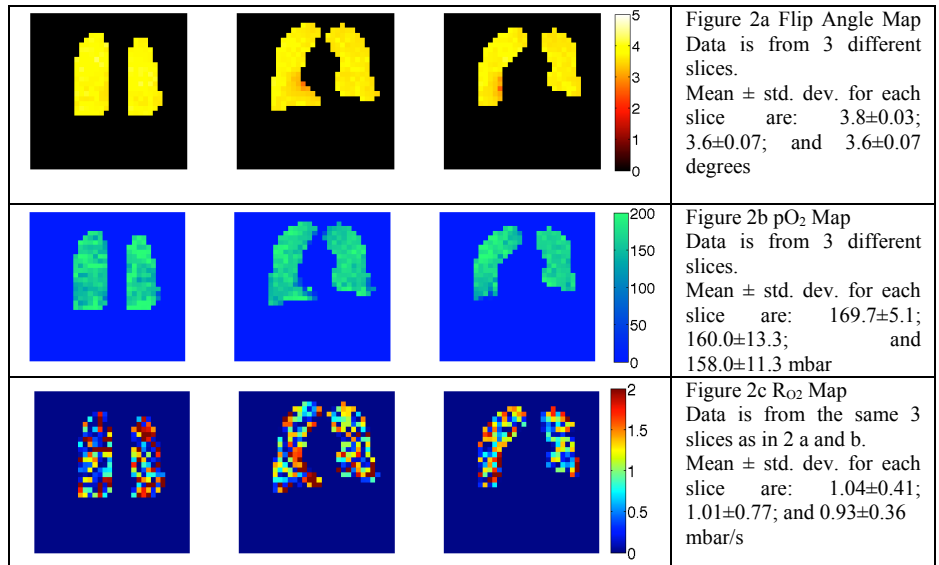


Figure 3. a – Histogram of the distribution flip angle value within the lung; b – distribution of the $p\text{O}_2$ values in the lung, c – the same for RO_2 .