Hyperpolarized ^{129}Xe Gas and Dissolved Phase Lung Imaging using IDEAL

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Introduction: Magnetic resonance (MR) imaging using hyperpolarized ^{129}Xe provides a non-invasive approach for probing lung structure and function. In addition to providing information about the alveolar spaces in the lung, ^{129}Xe is able to diffuse across the blood-gas barrier giving rise to a chemical shift in compartments such as tissue and red blood cells (RBC's) on the order of 200 ppm, enabling distinct analysis. Using tools sensitive to these resonances, measurements of ventilation (V), perfusion (Q) and diffusing capacity of xenon (D_{Xe}) are possible [1,2]. In order to obtain simultaneous V, Q and D_{Xe} maps, ^{129}Xe chemical shift information can be acquired using a dynamic spectroscopic imaging approach. We propose to use a modified Dixon method called IDEAL (Iterative Decomposition of Water and Fat with Echo Asymmetry and Least-Squares Estimation), which incorporates a series of time-shifted gradient echoes to separate chemically-shifted species from the background field inhomogeneities using the phase of the MR signal. IDEAL has been used extensively for fat-water separation in ^{1}H imaging [3]. IDEAL uses prior knowledge of the chemical shifts of the signals being acquired to encode both spectral and spatial information in each line of k-space and is therefore well-suited for hyperpolarized ^{129}Xe, since the very large available magnetization is non-renewable. We present the application of IDEAL for simultaneous gas and dissolved phase hyperpolarized ^{129}Xe imaging in a phantom as well as present preliminary *in vivo* results in the rat lung.

Methods: *In vivo* ^{129}Xe MR Imaging was performed at 3T (GEHC, MR 750) corresponding to a xenon frequency of 35.34 MHz. A commercial, rat-sized quadrature birdcage coil (Morris Instruments Inc., Ottawa, ON) and a home-built insert gradient set with maximum gradient values of 50 G/cm optimized for rodents were employed for rat imaging measurements. Experiments were performed on healthy Sprague Dawley rats (400 ± 30 g) following an animal care protocol approved by the *Animal Use Subcommittee of the University Council on Animal Care at the University of Western Ontario*. Rat lung hyperpolarized ^{129}Xe 2D IDEAL images were obtained in the coronal plane using a fast spoiled gradient recalled echo (SPGR) method with a VFA approach and centric k-space sampling (TE1=1.4ms, TE2=1.8ms, TE3=1.6ms, TR=2.6 ms, 15 x 15 cm, 32 x 32 pixels, BW=8kHz). Natural abundance hyperpolarized ^{129}Xe gas was obtained using a continuous flow polarizer and cryo-trap, giving final polarizations of approximately 6%. A MR-compatible mechanical ventilator was employed for delivery of hyperpolarized ^{129}Xe gas to the rat from a Tedlar bag. A 2L plastic bottle filled 50/50 gas (26 mL HP ^{129}Xe, N_2 balance) and water was used as a test phantom. 2D phantom IDEAL images were obtained in the axial plane using a fast SPGR method with a variable flip angle (VFA) approach and centric k-space sampling (TE1=1.4ms, TE2=1.8ms, TE3=1.6ms, TR=2.6 ms, 26 x 26 cm, 32 x 32 pixels, BW=16kHz). Commercial, rat-sized quadrature birdcage coil and MR 750 clinical imaging gradient set were used. Dissolved phase and gas phase images were generated from the imaging data with a modified IDEAL reconstruction that accounted for the chemical shift (6.7 kHz) between dissolved and gaseous ^{129}Xe.

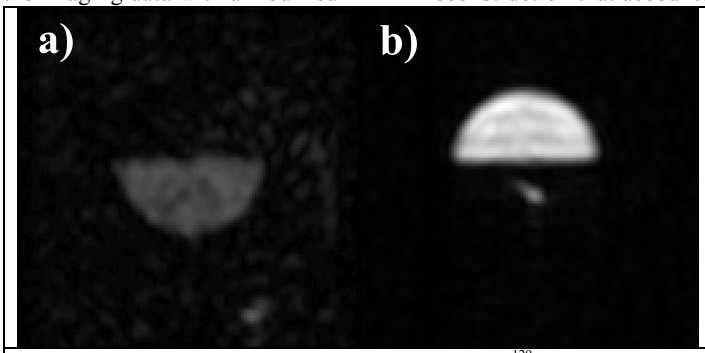

Figure 1: Axial 2D IDEAL images of hyperpolarized ^{129}Xe in bottle phantom containing water (bottom) and gas (top). Dissolved and gas phases are shown separately in (a) and (b) respectively. (image display window and levels have been adjusted appropriately).

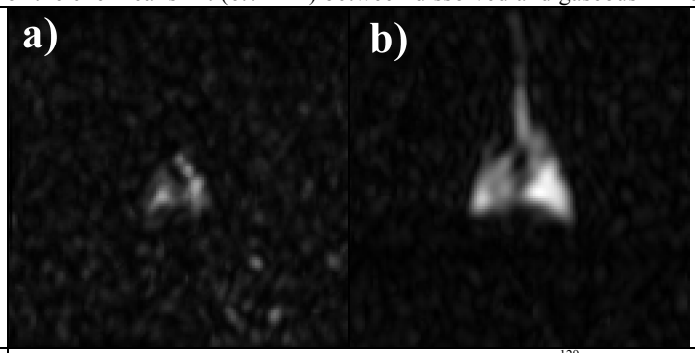

Figure 2: Coronal 2D IDEAL imaging of hyperpolarized ^{129}Xe rat lung. Dissolved and gas phases are shown separately in (a) and (b) respectively. (image display window and levels have been adjusted appropriately).

Results and Discussion: Figure 1 shows a set of axial IDEAL images obtained from the bottle phantom containing hyperpolarized ^{129}Xe in both gas phase and dissolved in water. The gas and dissolved phases of ^{129}Xe can be clearly distinguished in these two images obtained simultaneously confirming the feasibility of this approach. Figure 2 shows preliminary in-vivo coronal IDEAL images obtained from the rat lung. Despite the low signal-to-noise ratio, these preliminary results demonstrate the feasibility of using IDEAL for simultaneous hyperpolarized ^{129}Xe imaging of the gas signal and the signal from the tissue and RBC compartments in the lung. In future, we expect to improve SNR by increased polarizations and potentially using xenon gas enriched in ^{129}Xe. By addition of another echo to this approach, the signal from lung tissue and RBC compartments can also be resolved (4). This would allow measurement of perfusion in addition to ventilation, which may be useful for detecting ventilation/perfusion (V/Q) mismatch [5]. By performing IDEAL at multiple time points following selective saturation pulses [1,2], this technique can be used to measure xenon diffusing capacity, a measure of gas exchange. These techniques may be useful in regional assessment of V/Q mismatch and inflammation in models of acute lung injury (ALI) such as gastric aspiration (GA) and radiation induced lung injury (RILI) where gas exchange is expected to be disrupted.

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