Compartment-Selective XTC MRI at 1.5T and 3T

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Introduction: Hyperpolarized xenon-129 (HXe-129) spectroscopy has revealed at least two dissolved-phase compartments in the lung: xenon bound to hemoglobin at 200-225 ppm (depending on the species and oxygenation level) and xenon dissolved in lung tissue and blood plasma at approximately 197 ppm [1,2]. In this work we demonstrate the feasibility of obtaining gas-phase depolarization maps in humans using Xenon polarization Transfer Contrast (XTC) MRI [3,4] by selectively inverting the magnetization in one of the two compartments [5]. By choosing sufficiently long delay times, these depolarization maps can be converted to blood-to-airspace-volume or tissue-to-airspace-volume maps. Preliminary results at 1.5T and 3T are presented.

Methods: Data were acquired in four healthy subjects either at 1.5T (Avanto, Siemens Medical Solutions) or at 3T (Trio). Flexible chest RF coils (Clinical MR Solutions, Brookfield, WI) were used for acquisitions at both field strengths. Enriched xenon gas (87% Xe129) was polarized by collisional spin exchange with an optically-pumped rubidium vapor using a prototype commercial system (Xemed LLC, Durham NH). All experiments were performed under a Physician's IND for imaging with HXe-129 using a protocol approved by our institutional review board. Informed consent was obtained in all cases. Each subject inhaled approximately one liter of gas containing a mixture of HXe-129 (~ 0.5 L), room air and oxygen; the Xe129 polarization was 15-20%.

Spectroscopy studies were performed at both field strengths in which 90° RF pulses of variable duration (5-15 ms) and center frequency (188-230 ppm) were used to identify the most appropriate bandwidth, center-frequency combination for selecting either of the two dissolved-phase compartments [6]. These RF pulses were then used in the contrast-generating segment of the XTC sequence. The two imaging segments of the XTC acquisition were asymmetric FLASH sequences (75% of *k*-space sampled) with excitation flip angles of 3.6° and 10.1°. The following parameters were used: non-selective excitation with a 160μs Gaussian RF pulse; matrix 76-96×128; TR/TE 16/8.1 ms; FOV 400 mm; receiver bandwidth 80 Hz/pixel. For a blood volume (tissue volume) map, the two FLASH image acquisitions were separated by a series of 95 (20) contrast-generating 180°/-180° RF pulse pairs with an inter-pulse delay of 20 ms, applied at the blood-phase (tissue-phase) resonance frequency of 224 (198) ppm for the XTC experiment or at -224 (-198) ppm for the control experiment.

Results: Gaussian RF pulses of 7-ms duration and centered at either 198 ppm or 224 ppm cleanly excite the tissue or blood xenon resonance, respectively, with minimal impact on the other peak (Fig. 1). Figure 2 depicts the tissue-selective depolarization maps obtained with XTC acquisitions at 1.5T and 3T (left) as well as the associated blood-selective depolarization maps (right). In our studies we found the tissue compartment in human lung to be approximately three times larger than the blood compartment. Note that measured depolarizations in the apices were lower than the actual values due to limited coverage of the RF coil in the head-foot direction.

Conclusion: Our spectroscopy studies indicate that 7-ms Gaussian RF pulses permit very selective excitation or inversion of the two peaks that make up the dissolved-phase region in the human lung. In fact, at 3 T, even 5-ms pulses are sufficiently selective. Employing such selective pulses in conjunction with an XTC MRI pulse sequence now permits information to be collected about gas exchange between the alveolar air spaces and the blood or the tissue compartment individually, instead of in aggregate form [3,4]. For instance, it may now be feasible to distinguish a mild case of emphysema from reduced pulmonary blood volume (e.g., due to lowered perfusion) or anemia, which provides a valuable extension to previous studies at 0.2 T [4]. Therefore, our findings will considerably increase the specificity of XTC MRI for the detection of pathological lung function changes. Additional studies planned for the near future will also address the question which field strength is most suitable for compartment-selective XTC MRI.

References: [**1**] Mugler III JP et al. MRM 1997; 37:809. [**2**] Wolber J et al. PNAS 1999; 96:3664. [**3**] Ruppert K et al. MRM 2000; 44:349. [**4**] Patz S et al. Acad Radiol 2008; 15:713. [**5**] Ruppert K et al. ESMRMB (2000); 240. [**6**] Chang Y et al. ISMRM 17 (2009); submitted.

Acknowledgements: Supported by NIH grants R41 CA128895, R41 HL091578, R01 EB003202 and R01 HL079077, and Siemens Medical Solutions.

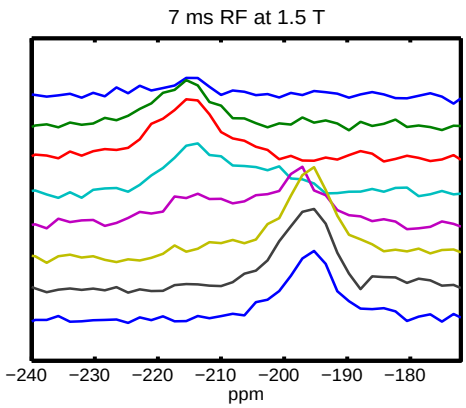

Figure 1. Excitation profiles for 7 ms Gaussian RF pulses at 1.5 T with center frequencies between 230 (top) and 188 ppm (bottom).

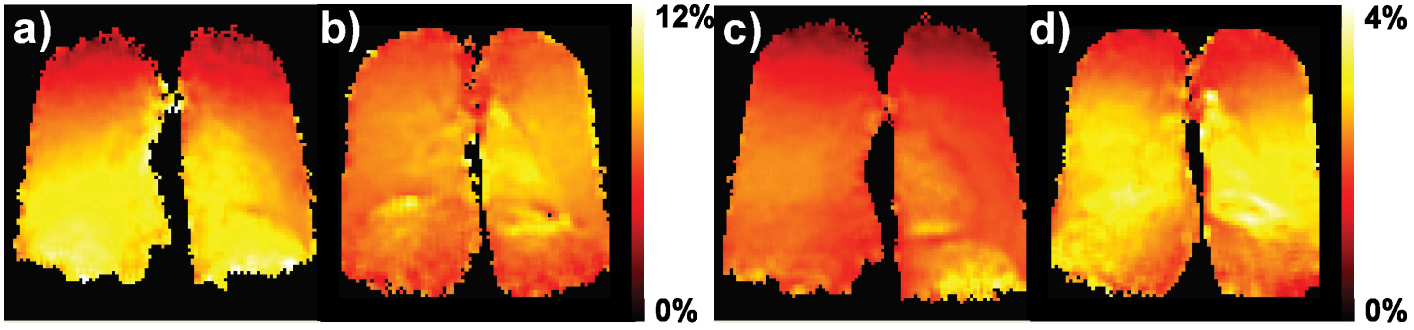

Figure 2. Tissue depolarization maps at 1.5 T (**a**) and 3T (**b**). The associated blood depolarization maps at 1.5 T and 3 T are shown in (**c**) and (**d**), respectively. The lower apparent depolarization in the apices is caused by limited RF coil coverage in the head-foot direction. Due to variations in flip angle calibration and relative lung inflation, the maps for the two subjects are not fully comparable.