Hyperpolarized Xenon-129 Dissolved-phase Signal Dependence on Flip Angle and TR

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Introduction: Upon inhalation approximately 1-2% of hyperpolarized xenon-129 (HXe129) dissolves in the lung parenchyma and gives rise to several resonances that are chemically shifted by approximately 200 ppm relative to the alveolar gas phase. Such a large frequency difference makes it feasible to either exclusively image the dissolved HXe129 with selective excitation pulses [1] or to image both phases simultaneously, appearing side-by-side in the image, by using a suitable imaging bandwidth [2]. Also, although the number of dissolved xenon atoms is small relative to those in the free gas, the two compartments stand in rapid exchange. Thus, for sufficiently long repetition times, the strong but non-equilibrium gas-phase magnetization serves as a reservoir that replenishes the dissolved-phase magnetization consumed by the imaging pulse sequence. However, due to the complexity of the gas-exchange and gas-transport processes, the functional information in the acquired images depends greatly on the selected imaging parameters. In this work we present our preliminary findings in rabbits at 1.5T for various repetition time (TR) / RF excitation flip-angle (FA) combinations.

Methods: Experiments were performed on a 1.5-T commercial whole-body imager (Avanto, Siemens Medical Solutions, Malvern, PA) using a custom-made transmit-receive birdcage RF coil (IGC Medical Advances, Milwaukee, WI). The imaging sequence was a 2D-projection gradient-echo sequence that employed RF excitation pulses with a truncated-sinc waveform of 2.31 ms duration centered 3,660 Hz downfield from the gas-phase resonance. The pulse parameters were chosen such that they provide a high FA at the dissolved-phase resonance (~202 ppm) and a homogeneously low FA at the gas-phase resonance (0 ppm). The following sequence parameters were used: matrix size 36×80; TR/TE 50-400/2.8 ms; FOV 280 mm; receiver bandwidth 110 Hz/pixel. Five New Zealand white rabbits (approximately 5 kg) were imaged. Each animal was anesthetized with a mixture of Xylazine 5 mg/kg and Ketamine 50 mg/kg, intubated, and placed in the xenon RF coil. Immediately before the pulse sequence was started the animal was ventilated with 30 cc of isotopically enriched xenon gas (~87% xenon-129), which was polarized to ~35% using a commercial prototype polarizer (Xemed LLC, NH). The protocol was approved by our Institutional Animal Care and Use Committee.

Results and Discussion: For the chosen pulse sequence parameters each acquired image depicts the HXe129 gas-phase signal to the left and the HXe129 dissolved-phase signal to the right, shifted relative to one another by approximately 32 pixels. Except for this well-defined shift along the frequency-encoding direction both images are fully registered. As illustrated by Fig. 1, the gas-phase signal increases with increasing FA and decreasing TR due to higher gas-phase excitation and reduced T1 decay, respectively. The behavior of the dissolved-phase magnetization, on the other hand, is much more complex since high excitation FAs maximize the fraction of the magnetization that is excited but also saturate all downstream magnetization. By the same token, short TRs minimize the impact of T1 decay while long TRs maximize the accumulation of HXe129 magnetization in the lung tissue and blood. From the upper right corner down to the lower left corner in Fig. 1, the dissolved-phase signal reflects less and less the lung tissue properties at the gas exchange sites but more and more the HXe129 distribution in the blood stream as emphasized by an ever clearer delineation of the major blood vessels, the left ventricle of the heart and the aortic arch. It is important to point out that such a low FA / long TR dissolved-phase component is not equivalent to a perfusion image, but rather contains information about the actual HXe129 gas transport from the alveolar airspaces all the way to the aorta. Any pulmonary or cardiac disease that affects this gas transport process will, at least in principle, manifest itself as an abnormality in such an image set. Also, since gas-phase and dissolved-phase information is available simultaneously, all dissolved-phase measurements are inherently quantitative because the gas-phase signal serves as a reference.

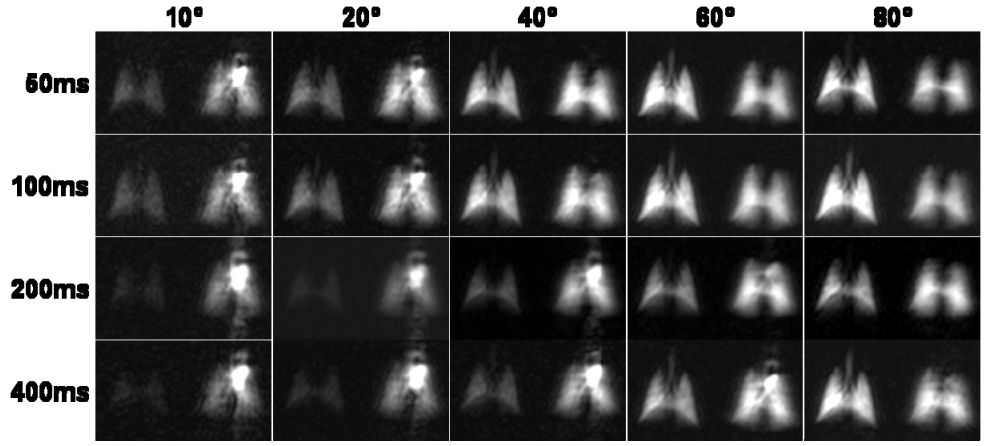

Figure 1. Signal dependence in simultaneously acquired gas and dissolved-phase images on the flip angle of the RF excitation pulse (rows) and the TR (columns). Note, that the listed flip angles are the nominal flip angles at the dissolved-phase resonance. The effective flip angle at the gas-phase frequency is only a small fraction of that value.

Conclusion: The simultaneous imaging of the gas-phase and the dissolved-phase magnetization allows the monitoring of HXe129 gas transport processes throughout the pulmonary and cardiovascular system up to the aortic arch. This is achieved by shifting the weighting of the dissolved-phase contrast from exchange-site dominant to blood-pool dominant through an adjustment of the TR/FA combination of the acquisition and is feasible despite a large overlap of the tissue and red blood cell resonances in rabbits.

References: **[1]** Driehuys B et al. 4th IWPFI, Boston, 2009. **[2]** Mugler III JP et al. MRM 1997;37:809-815.

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