# Sensitivity Improvements for XTC MRI with Spiral Acquisitions

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**Introduction:** Xenon polarization transfer contrast (XTC) MRI is a promising technique that exploits the gas exchange of Xe-129 between the alveolar gas phase and the lung parenchyma to obtain information about lung function and certain parameters of pulmonary physiology (1,2). These parameters are extracted from gas-phase depolarization maps that are obtained in a 3-step process during a single breath-hold. In the first and third steps the gas-phase signal in the lung is sampled with a rapid 2D gradient-recalled echo (GRE) pulse sequence, such as 2D FLASH. In the second step a series of appropriately spaced frequency-selective 180°/-180° radio frequency (RF) pulse pairs, centered at the resonance frequency of Xe-129 dissolved in the lung parenchyma, encodes information that characterizes the ongoing gas exchange processes into the gas-phase signal. While the amount of magnetization expended for steps 1 and 3 determines the signal-to-noise ratio (SNR) of the resulting depolarization maps, step 2 creates the desired contrast. Thus, for an optimal contrast-to-noise ratio (CNR), as much of the non-equilibrium magnetization of the inhaled hyperpolarized Xe-129 as possible should be reserved for contrast generation while simultaneously a high SNR in the acquired gas-phase images needs to be maintained.

Since hyperpolarized noble gas MRI has the property that, for a fixed total sampling time for the acquisition, the image SNR increases with a decreasing number of RF excitation pulses, it is possible to boost the SNR without affecting the amount of magnetization used in the process. As a compromise between maximizing the SNR and minimizing the extent of image artifacts, we investigated the usefulness of a spiral image acquisition with 8, 16 and 32 interleaves instead of the conventional rectilinear-trajectory 2D FLASH acquisition. As a metric of performance we evaluated the SNR of the ventilation images obtained during step 1 of the XTC MRI technique for 2 rabbits.

**Methods:** All experiments were performed on a 1.5-T commercial whole-body imager (Sonata, Siemens Medical Solutions, Malvern, PA). The RF coil was a custom-made transmit-receive birdcage coil (IGC Medical Advances, Milwaukee, WI). The spiral *k*-space trajectory consisted of 8, 16 or 32 spiral interleaves along which 2048, 1024 or 512 data points, respectively, were sampled. The data were gridded onto a 128×128 matrix and Fourier transformed. The following sequence parameters were used for 8, 16 or 32 interleaves, respectively: Non-selective excitation with a 160μs Gaussian RF pulse; flip angle 12°, 8° or 6°; TE 0.16ms; TR 22.4, 12.2 or 7.1ms; FOV 340mm; bandwidth 49, 98 or 195Hz. Between image acquisitions a series of 20 180°/-180° RF pulse pairs with an inter-pulse delay of 40ms was applied at the dissolved-phase resonance. In this way the 202ppm frequency shift between the gas phase and dissolved phase, and the rapid exchange between the two, is exploited to generate image contrast. The control experiment employed a shift of -202ppm.

Two New Zealand rabbits were anesthetized with a mix of Xylazine 1mg/kg and Ketamine 0.1mg/kg and intubated with an endotracheal tube. The animals were ventilated with 40cc of isotopically enriched (85% $^{129}$Xe) xenon gas, polarized to approximately 10-15% via spin exchange with an optically pumped rubidium vapor (Model IGI 9600Xe Xenon Polarizer, MITI, Durham, NC). The polarizer had been optimized to increase the achievable polarization levels. The protocol was approved by our Institutional Animal Care and Use Committee.

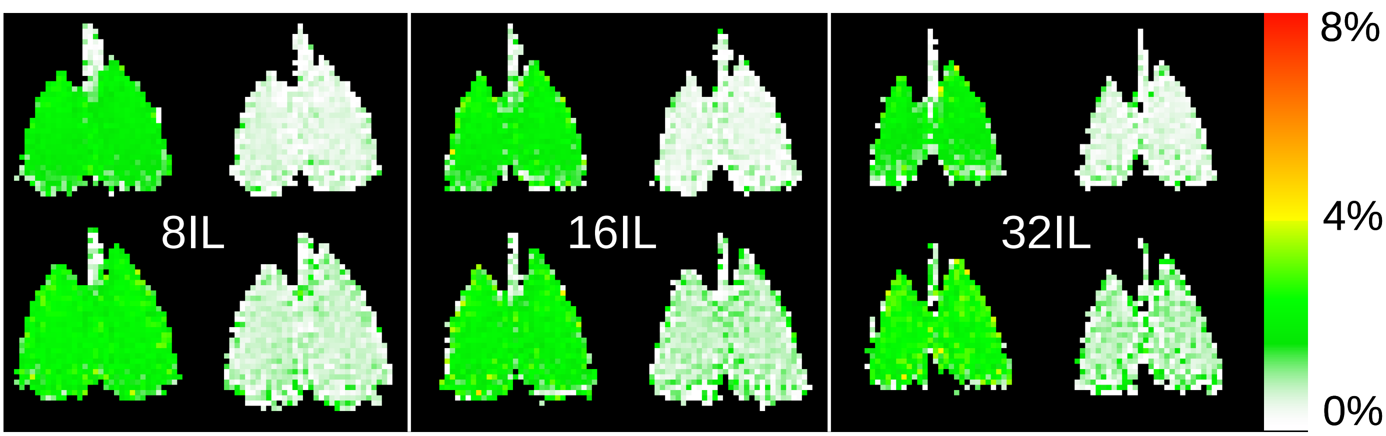


**Figure 1:** Depolarization maps for 2 rabbits (rabbit #1: top row; rabbit #2: bottom row) acquired with spiral XTC MRI sequences with 8, 16 and 32 interleaves (IL). Each sequence was run in exchange (left map of each pair) and control (right map of each pair) configuration.

**Results:** We found on average that the SNR for ventilation images increased by 31% with 16 interleaves and by 92% with 8 interleaves compared to that for ventilation images acquired with 32 interleaves. Figure 1 depicts the depolarization maps for the 2 rabbits obtained with the various spiral XTC MRI sequences. The SNR gains for the sequences with fewer interleaves also translate into smoother depolarization maps with a less noisy appearance. The SNR of the previously employed Cartesian 2D FLASH sequence (2) was approximately equivalent to that for 32 spiral interleaves.

**Discussion:** Exchanging the Cartesian FLASH readout modules in an XTC MRI acquisition for an 8-interleave spiral readout increases the SNR of the ventilation images by almost a factor of 2. Since the magnetization available for contrast generation remains unchanged, the CNR in the depolarization maps will be boosted by a factor of 2 as well. Therefore, it is reasonable to expect that this optimization will result in a considerable increase in sensitivity to pathological changes in lung function and physiology.

**References**

[1] Ruppert K, Brookeman JR, Hagspiel KD, Mugler III JP. MRM 2000; 44:349-357.
[2] Ruppert K, Mata JF, Brookeman JR, Hagspiel KD, Mugler III JP. MRM 2004; 51:676-687.

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