High-Resolution Diffusion and Ventilation MRI: Hyperpolarized Xe-129 versus He-3 in a Large Animal Model

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Introduction: Up to now hyperpolarized Xe-129 has not been widely used for ventilation or diffusion MR imaging of the lungs when compared with He-3, primarily due to the lower polarizations obtainable with Xe-129. But a limited worldwide supply of He-3 and a price that likely will increase with demand in the future has fostered efforts to increase the Xe-129 polarization and to use isotopically enriched Xe-129. Higher polarizations could make Xe-129 the likely preferred choice for hyperpolarized-gas MR imaging. It is also theoretically plausible that the Xe-129 ADC may be more sensitive to early disease when structural changes are on a smaller scale because of xenon's lower diffusion coefficient. This project was designed to compare the potential of high-resolution ventilation and diffusion MRI using hyperpolarized Xe-129 at the current polarization levels of 10-20% in a large animal to hyperpolarized He-3.

Methods and Materials: Experiments were performed using two 30-kg red-tick hound dogs. The dogs were anesthetized with Pentobarbitol 0.5cc/kg, intubated with an endotracheal tube and placed in a dual-tuned H-1/Xe-129 transmit/receive birdcage RF coil (USA Instruments, Aurora, OH) or in a He-3 flexible RF wrap coil (IGC Medical Advances, Milwaukee, WI). The animal protocol was approved by our Institutional Animal Care and Use Committee. Imaging was performed on a 1.5-Tesla commercial whole-body scanner (Magnetom Sonata, Siemens Medical Solutions, Malvern, PA), modified by the addition of a broadband amplifier, for operation at the frequencies of 17.6 MHz for Xe-129 and 48.4 MHz for He-3.
Each set of xenon and helium ventilation or diffusion-weighted images was acquired in less than 10 seconds during a breath hold following the inhalation of 500 cc of hyperpolarized gas. We used isotopically enriched Xe-129 (85%; Spectra Gases, Alpha, NJ), with polarization levels of 14-16% for the xenon experiments, and a mixture of 200 cc of N_2 and 300 cc of He-3 polarized at 35-40% for the helium experiments. Hyperpolarized Xe-129 gas was generated using a modified version of a commercial system (Model 9600 Xenon Polarizer, Magnetic Imaging Technologies Incorporated, Durham, NC). Hyperpolarized He-3 was generated using a commercial He-3 polarization system (Amersham Health, Durham, NC).
For the ventilation image sets the same FLASH sequence and exactly the same parameters were used for both gases: 10 slices with 15-mm thickness and an in-plane resolution of 4.4 x 3.3 mm^2; matrix 72x128; TR/TE 7.5/3.17 ms; FA 10°. For diffusion imaging two FLASH-based sequences with different b values were used (b=0 and 10 s/cm^2 for Xe-129; b=0 and 4 s/cm^2 for He-3) but with similar parameters: 5 slices with 30-mm thickness and in-plane resolution of 4.4 x 3.3 mm^2; matrix 72x128; TR/TE 11/6.7 ms (for He-3); TR/TE 16/11 ms (for Xe-129); FA 10°.

Results: All images shown below are from the same animal. The Xe-129 ventilation images (Fig. 1) show a mean SNR of approximately 40, and the mean SNR for the He-3 ventilation image (Fig. 2) is 80. The measured mean ADC values for the healthy dog lungs were 0. 029 ± 0.0068 cm^2/s for Xe-129 (Fig. 3) and 0.153 ± 0.027cm^2/s for He-3 (Fig. 4).

Discussion: The Xe-129 and He-3 ventilation images are similar, showing the same anatomic and physiologic information. A higher SNR was achieved with He-3, but the SNR with Xe-129 is more than sufficient for the spatial resolution used. The ADC maps obtained with Xe-129 show a high-resolution, low-noise depiction of the regional ADC values. The ADC values are consistent with the literature (1).

Reference: 1. Chen XJ et al. Magn Reson Med 2000; 42:721-728.

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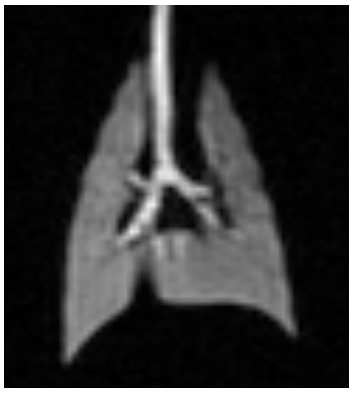

Figure 1. Xe-129 (85% enrich.) ventilation image; 15-mm slice thickness; 4.4 x 3.3mm voxel size.

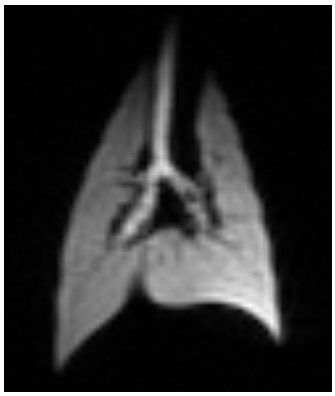

Figure 2. He-3 ventilation image; 15-mm slice thickness; 4.4 x 3.3 mm voxel size.

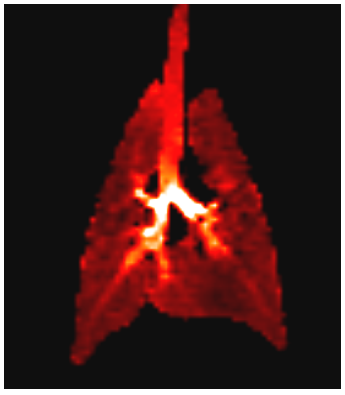

Figure 3. Xe-129 (85% enrich.) ADC map; 30-mm slice thickness; 4.4 x 3.3mm voxel size.

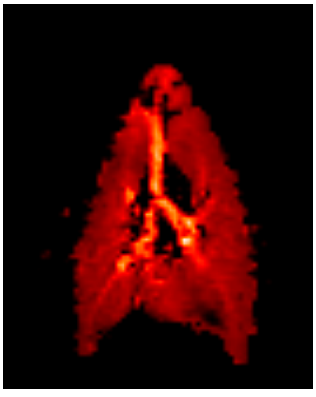

Figure 4. He-3 ADC map; 30-mm slice thickness; 4.4 x 3.3mm voxel size.