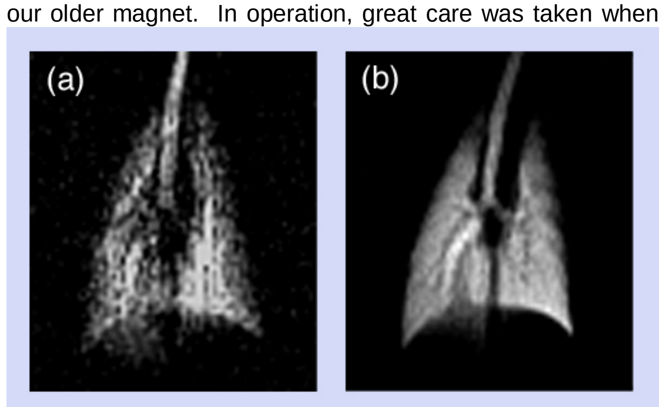
Highly polarized Xe-129 and resulting improvements in MR image quality

G. D. Cates[1], J. R. Brookeman[1], K. D. Hagspiel[1], J. F. Mata[1], J. P. Mugler III[1], A. G. Reish[1], W. A. Tobias[1], H-T. J. Wang[1]
[1]University of Virginia, Charlottesville, Virginia, United States

Introduction: While hyperpolarized noble-gas imaging has proven to be a useful tool for imaging, most of the published images have been made using He-3 rather than Xe-129. The reason for this is primarily image quality. Low polarizations, a smaller magnetic moment, and a natural abundance of only 26% all contribute to a substantially smaller signal from Xe-129. With higher polarization, however, image quality is greatly improved. In this abstract we present a comparison of two Xe-129 ventilation images of canine lungs, one made with 3% polarization and one made with 11% polarization. A dramatic increase in the signal-to-noise ratio (S/N) was observed despite a smaller voxel size. The higher Xe-129 polarization levels were achieved through a series of modifications to a commercial prototype Xe-129 polarizer. We describe those modifications, and the potential for further improvement.

Methods: Hyperpolarized Xe-129 MRI was performed on a canine model using a 1.5T whole-body scanner (Magnetom Sonata; Siemens Medical Solutions, Malvern, PA). The studies were performed using a protocol approved by our Institutional Animal Care and Use Committee. A female red tick hound (30 kg) was anesthetized with Pentobarbitol 0.5 cc/kg, intubated with an endotracheal tube, and placed in a dual-tuned 1H/129Xe transmit/receive birdcage RF coil (USA Instruments, Aurora OH). Approximately 500 ml of polarized xenon was dispensed into a Tedlar plasic bag (Jensen Inert Products, Coral Springs FL) which was gently squeezed, forcing the xenon into the dog's lungs. At the end of the imaging sequence, which was less than 8 sec, a valve was opened allowing the dog to breathe room air. Images were produced using a FLASH sequence adapted to provide reasonable image quality for each of the two polarization levels. For the 3% polarized gas, a single 180 mm slice was used, with a 112x128 matrix, a 43.75 cm x 50.00 cm FOV, a 25° flip angle and a TR/TE of 7.5/3.17 ms. For the 11% polarized gas, three 50 mm slices were used (only one is shown), with a 112x128 matrix, a 36.75 cm x 42.00 cm FOV, a 10° flip angle and a TR/TE of 7.5/3.17 ms.

Xenon of natural isotopic abundance was polarized by spin-exchange optical pumping using a modified prototype commercial system (Model 9600 Xenon Polarizer; Magnetic Imaging Technologies Inc., Durham NC) that is based on a flowing-gas concept[1]. The modifications included increasing the laser power to approximately 105 Watts using three high-power fiber-coupled diode-laser array systems (Coherent Inc., Santa Clara CA). The light from the three laser systems was combined and sent through a homogenizer before being circularly polarized and focused onto the glass cell in which the gas mixture was polarized. Another modification included flat-windowed pyrex cells whose interior surface had been coated with an aluminosilicate sol-gel coating[2]. The final modifications involved an assembly containing liquid nitrogen that is used to cryogenically strip out the xenon from the flowing-gas mixture and accumulate it as xenon snow in a magnetic field of 2kG. Here a larger volume magnet and an accompanying cold finger (Part Nos. 02740 and 02045, Amersham Health, Durham NC) were purchased and adapted to our apparatus. This modification ensured that the xenon snow collected in a high-field region and not in the fringe field of our older magnet. In operation, great care was taken when thawing the xenon snow to minimize the amount of time required for the xenon to sublimate.



Results: We have obtained a substantial increase in the polarization of the Xe-129 produced by our apparatus and delivered to the subject. Taking advantage of these improvements, we have made a comparison of images that utilized 3% polarized Xe-129 in (a) and 11% polarized Xe-129 in (b). We observe an improved S/N of 23 in (b) as compared to 9 in (a) despite using smaller voxels. With the modifications and precautions described above, we now consistently achieve polarization levels in the 10-15% range when preparing 500-600 cm^3 of gas.

Discussion: Clearly, the morphological detail evident in image (b) is superior to that revealed in image (a). While we only present one example here, dramatically improved image quality associated with higher polarization levels is something we now routinely observe during both animal and human Xe-129 lung imaging studies. By bringing polarization levels into the 10-15% range, we appear to have crossed a threshold beyond which Xe-129 imaging has become more practical and useful. Looking toward the future, we note that our work on improving polarization is still at an early stage, and we anticipate that Xe-129 polarization levels of 30-40% will eventually be achieved.

References: 1. Driehuys B, Cates GD, Miron E, Sauer K, Walter DK, and Happer W, Appl.. Phys. Lett. 1996 69:1668-71.

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