Very Low Field 15 mT System for Hyperpolarized Noble Gas MRI

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Introduction

Conventional proton magnetic resonance imaging (MRI) employs medium to high static magnetic fields (0.5-7 T) to obtain observable signal at thermal Boltzmann polarization. Although the improved signal-to-noise ratio (SNR) induced by high field increases both the spatial and temporal resolution of the image, superconducting magnets used by high field MRI systems are expensive, heavy, and not feasible for gas-phase MRI at thermal polarization. However, the polarization of hyperpolarized (HP) noble gases, produced by spin-exchange optical pumping, does not depend on static magnetic fields [1]. There is great promise to construct a low field HP gas MRI system for studies of void spaces such as the lungs, which has the advantage of being low-cost, portable for space research, and even might be available to patients with artificial transplants, e.g. pacemakers [2].

Materials and Methods

Fig 1. 15mT very low field MRI system.

Figure 1 shows a 15mT solenoid electromagnet of 71 cm ID made by Resonance Research with an optimized field homogeneity of 20 ppm over a 30 cm diameter spherical volume (DSV). The bore size is sufficient for imaging large patients. The magnet is situated inside an RF enclosure made by ETS-Lindgren with the attenuation of electrical fields and plane waves down to 100 db at 10 KHz. The three axis gradient coils (X,Y,Z) are driven by three individual gradient amplifiers, which are Techron 8606s in our system. For a stable system, the frequency responses of the amplifiers have to be matched to the impedances of the gradient coils. The noise on the gradient coil was significantly reduced by using a set of custom-made gradient filters (ETS-Lindgren) which have a band pass only up to 20 KHz. We improved the original design of the magnet cooling system by adding a cooling plate with water hoses for cooling water connections in between the gradient coils and the magnet coils. It was found that this new improvement dramatically improves the cooling efficiency and allows our magnet to run 24/7 rather than only 4 to 5 hours per day with the previous design. The system was interfaced to a Resonance Instruments Ultra Maran console. Our RF coil is home-made, consisting of a pair of 20-turn coils of 10.5 cm ID shown in Figure 2, which was tuned to 638 KHz for ^{1}H and 486 KHz for ^{3}He. ^{3}He gas was produced via spin-exchange with polarized rubidium optically pumped by a 60W laser diode array at 794 nm. The polarization of ^{3}He achieved was 20%. After a healthy volunteer, positioned inside the magnet, inhaled 1 liter of HP ^{3}He gas and held their breath for 15 sec, gradient echo imaging was performed with a matrix size of 128 (frequency encoding) by 64 (phase encoding) in K-space. The raw data was zero filled to 128 by 128 before 2D Fourier transform. The FOV was 40 cm x 40 cm, and TE= 13ms and TR=200ms.

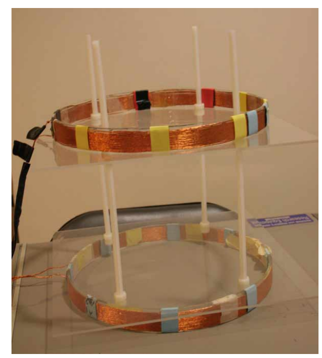

Fig 2. Home-made lung coil pair for lung imaging.

Results and Conclusion

Figure 3 shows a human lung image using HP ^{3}He at 15 mT. It shows the left and right side lobes of lungs, and part of the trachea is also visible. This result on a human successfully demonstrates the low field MRI system for hyperpolarized noble gas. Although the image quality at low field is not as good as that acquired at high field, the further improvement of SNR and resolution will be helpful. Our study shows the potential for the future development of a portable, inexpensive system for diagnosis of lung disease and evaluation of treatment, not only in rural areas but perhaps also in space due to the much lighter weight of the system.

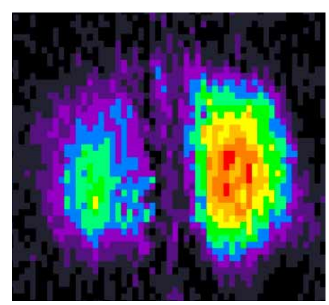

Fig 3. Human lung image using HP ^{3}He at 15mT.

Sponsors

NSF Grant BES-0093448.

References

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