Low Field MR Imaging of Laser-Polarized Noble Gas

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Purpose

The purpose of this study was to demonstrate the utility for lung imaging of laser-polarized (LP) noble gas MRI at low magnetic fields (< 50 gauss). The high spin-polarizations characteristic of LP ^{3}He and ^{129}Xe obviate the need for a large (~ 1 Tesla) polarizing magnetic field, while working at low magnetic fields offers advantages for various experimental situations. Our recent results include low field T_1 and T_2* measurements, as well as images, of LP ^{3}He inside excised rat lungs.

Introduction

Laser-polarization of ^{3}He and ^{129}Xe enables high resolution gas-space imaging, most notably of the lungs [1]. Unlike conventional proton MRI, the spin polarization of LP noble gas is independent of the main magnetic field, relying instead upon optical pumping details such as available laser power and gas pressures. For example, one can achieve greater than 10% polarization in ^{3}He, which is nearly five orders of magnitude larger than the polarization of ^{1}H in a clinical magnet. Therefore, with suitable (low frequency) electronics, one can expect effective gas-space imaging at low magnetic fields. There are significant benefits to working at reduced magnetic fields, and various groups are investigating low field MRI with LP noble gases [2,3]. We have developed a novel system for noble gas MRI at ~ 20 gauss and imaged glass phantoms filled with LP ^{3}He under circumstances that highlight the benefits of low field MRI [4]. Recently, we used this system to image LP ^{3}He in excised rat lungs.

Methods

A home-made wire-wound solenoid, capable of providing a field of up to 100 gauss, was used as the primary magnet. Imaging gradients were produced with standard design Golay and anti-Helmholtz coils, while orthogonal sets of Helmholtz coil pairs were used as drive and pickup coils. An unamplified Wavetek Model 10 function generator was used as the r.f. source, and provided a reference frequency for a 100 kHz lock-in amplifier used in signal detection. For convenience, r.f. pulse timing, gradient control, and data acquisition were handled by a Bruker AMX console.

^{3}He was polarized via spin-exchange with optically pumped Rb using an Opto Power 15 W fiber-coupled laser diode array. Images were taken with a standard FLASH sequence, using 128 concentric phase encode steps and no slice selection or signal averaging. The Larmor frequency of ^{3}He was 67 kHz, corresponding to a field of 20.6 gauss.

Results

Fig. 1 is an example image of LP ^{3}He imbibed into excised rat lungs; the resolution is approximately 1 mm^2. T_1 of the gas inside rat lungs was found to range from 16-63 seconds, consistent with reports of similar experiments performed at high field, and presumed to be dependent on the amount of depolarizing paramagnetic oxygen present.. At low field, we measured the LP ^{3}He T_2* to be greater than 100 msec in rat lungs, which is much longer than the approximately 5 msec T_2* observed for guinea pig and human lungs at 2 T and 1.5 T [5,6], respectively. This longer ^{3}He T_2* is a result of the reduced effect of magnetic susceptibility heterogeneity at low magnetic fields.

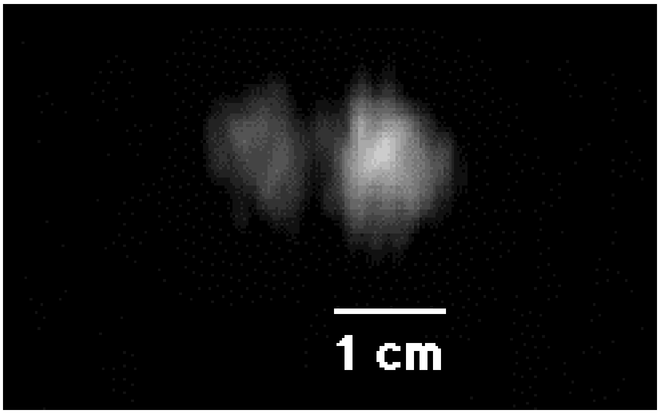

Figure 1. Coronal view MRI at 20.6 gauss of excised rat lungs filled with laser-polarized ^{3}He. Total image FOV was ~ 10.9 cm x 8.1 cm.

Discussion

We have shown the efficacy of low field imaging of laser-polarized noble gas, in particular for use in biomedical gas-space imaging. The benefits of working at low magnetic fields, such as longer T_2* in the lungs, may allow the application of more sophisticated imaging techniques (*e.g.*, EPI) and spectroscopic methods (*e.g.*, time-dependent gas diffusion measurements). While our existing low field MRI system was intended for small scale samples, it is straightforward and inexpensive to build a larger system suitable for animal or human use.

References

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