Low Field Lung Imaging Using Hyperpolarized ^{3}He

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Introduction

Hyperpolarized gas imaging offers the best method to image air spaces and study lung ventilation [1]. The aim of this work is to investigate the feasibility of lung imaging at low field (0.15T) using small quantities of hyperpolarized ^{3}He gas. We have made a comparison of pulse sequences including RARE and FLASH. In addition we have explored the use of tagging as a method of monitoring lung motion.

Methods

All imaging experiments where carried out on a 0.15 T elliptical bore ceramic ferrite permanent magnet, with a horizontal field direction (perpendicular to patient axis). The system utilizes separate receive and transmit coils. The advantage of such an arrangement is that the transmit coil can be made to produce a uniform B_1 field, while the receive coil can be designed (for SNR reasons) to be in close proximity of the region of interest, without altering the B_1 characteristics. A set of receive chest coils were tuned for both proton (6.219 MHz) and ^{3}He (4.734 MHz) imaging.

The hyperpolarized ^{3}He gas is produced in a gas station situated in very close proximity to the imaging system. The ^{3}He is polarized by direct optical pumping using a 50mW laser tuned to 1083nm [2]. The optical pumping occurs at low pressure (5mbar) where the process is most efficient. We achieve a typical polarization of between 20-40% in 2 cm^3 of ^{3}He STP gas. The low pressure hyperpolarized ^{3}He is subsequently mixed with ^{4}He to bring the pressure up to one atmosphere for inhalation. The total time taken to polarize a new sample of ^{3}He and administer to the volunteer is less than 20 minutes.

The gas is prepared in a tedlar medical bag (T_1=25min) and transported to the scanner in a 1mT field provided by a solenoid.

Imaging Sequences

Rapid Acquisition Refocused Echoes (RARE)

FLASH and RARE sequences are commonly used for imaging hyperpolarized gases. We have tried both sequences and we have found that RARE is particularly well suited to hyperpolarized ^{3}He imaging at low field [3], providing highly efficient usage of the non-equilibrium polarization. The RARE sequence used here has an echo time of 18ms and a total acquisition time of 1167ms with an image matrix size of 64*64.

Tagging

The aim of the tagging sequence [4] is to produce a spatial modulation in the magnetization prior to imaging, which is sensitive to motion and diffusion. This can be achieved by applying two non-slice selective pulses separated by a gradient. The direction of the tag gradient was superior-inferior and the applied tag spacing varied from 15-20mm. RARE images were taken at times varying between 100-1000ms after the tagging pulses.

Results

Initially a RARE sequence was run without any of the slice, phase or read gradients applied. The sequence is then equivalent to a CPMG sequence. Using an inter-echo spacing of 50ms and 128 refocusing pulses we obtained a typical T_2 value of 2.4+-0.2 s within the lung.

A non-slice selective coronal lung image using a RARE sequence is shown in figure 1. The SNR in this image is approximately 60:1.

Figure 1: Cornal RARE image.

Figure 2 shows a projected coronal tag image of a ^{3}He in the lungs during rapid inspiration. The time between tagging and imaging was 1s and the duration of the tagging gradient was 1ms with an amplitude of 0.5mT/m.

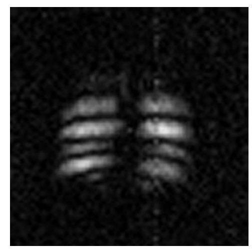

Figure 2: Coronal Tag Image

Discussion

The images presented here clearly show the filling of the lung air spaces with ^{3}He (see figure 1). The good SNR indicates that only a small amount of hyperpolarized ^{3}He (equivalent to 20 micro moles) allows high quality non-slice selective images to be produced. Figure 2 shows very clearly that it is possible to tag the ^{3}He gas within the lung. With a resolution of 5-7mm the tagged images show the expected modulation in image intensity. For example, during inspiration we observe that the stripes become curved indicating the regions of greatest motion. This tagging technique is thus potentially useful in lung motion studies using hyperpolarized gas.

For the future, a compressor and a 2W laser have been installed and these will increase the density of the polarized spins and therefore provide significantly higher SNR.

Acknowledgements

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References

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