Hyperpolarized Noble Gas MR Imaging SNR comparison between 73.5 mT and 3 T in Rat Lung

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Introduction

In Hyperpolarized Noble Gas (HNG) MR imaging (i.e. ^{129}Xe and ^{3}He), the available magnetization is independent of magnetic field strength. Above a cut-off Larmor frequency when the sample (i.e. body) noise dominates the RF coil noise [1], the signal-to-noise ratio (SNR) is expected to decrease with field for band-matched imaging due to a reduction in the transverse relaxation time, T_2* [2]. It has been previously demonstrated that the maximum SNR is expected to be at high fields (> 3T) for the small coils typically used for rodent lung imaging [3]. However, this SNR advantage of higher fields can potentially be offset by improved coil design resulting in comparable HNG imaging performance at low fields for rodent lung imaging. In particular, SNR improvements of up to 200% have been demonstrated in rat lung at 73.5 mT using Litz wire coils compared to regular copper [4]. Furthermore, the higher number of turns possible at low frequencies predicts further improvements in SNR for HNG imaging of rat lung. The SNR improvements possible together with the long T_2* available at these low fields, will permit further study of alveolar oxygen partial pressure [5] and long range diffusion [6] in rat lung. In this work the magnetic field strength dependence of the SNR for HNG MRI of rat lung is investigated theoretically and *in vivo*, using multi-turn Litz wire coils at 73.5 mT and compared to images obtained at 3 T using ^{129}Xe and ^{3}He.

Methods

Theoretical SNR field strength dependence was estimated as described previously by Parra-Robles *et al* [2]. The SNR improvement using Litz wire coils was simulated by reducing the skin effect dependence on the coil noise and increasing the number of turns at low fields. ^{129}Xe and ^{3}He images were obtained at 73.5 mT and 3 T in Sprague Dawley rats ventilated with a custom ventilation system using a University-approved animal care protocol. Rat imaging at 73.5 mT was performed using a broadband, variable field (0.01 – 0.15 T) MR imaging system [7]. Optimized Litz wire saddle coils of 48 and 34 turns were used for ^{129}Xe and ^{3}He respectively. Imaging of the same rats at 3T (MR750, GEHC) system was performed using a transmit-receive birdcage coil and a high performance insert gradient coil (G = 17 G/cm). Hyperpolarized xenon gas was produced by spin exchange optical pumping using a home-built, continuous-flow polarization system delivering 5mL/s gas mixture of 1 % xenon gas (enriched to 99% ^{129}Xe) with polarizations up to 15%. The polarizer used a 60W diode array laser (λ=794.8 nm, Coherent, Santa Clara, USA). Hyperpolarized ^{3}He was produced by a turn-key polarizer (Helispin®, GEHC) providing polarizations up to 40%.

Images were acquired at both fields using a 2-D gradient echo sequence with 64×64 pixels with similar TR/TE of about 1.3/0.7 ms and bandwidths of 2 kHz for imaging at 73.5 mT and ^{129}Xe imaging at 3 T. ^{3}He imaging at 3 T used 128×128 pixels and bandwidth of 31.25 kHz. Image SNR values were estimated using the mean value of a homogeneous area of image signal divided by the standard deviation of the noise in the background. The SNR values were corrected for differences in bandwidth, resolution, flip angles, polarization of the gas T_2* as described previously [8].

Results and Discussion

Figure 1 shows *in vivo* rat lung images in the coronal plane acquired at both field strengths for both ^{129}Xe and ^{3}He. Table 1 show the expected and measured SNR ratio between 3T and 73.5 mT for both ^{129}Xe and ^{3}He.. Differences in predicted SNR values for ^{129}Xe and ^{3}He are due to the differences in gyromagnetic ratio. Due to the improvement provided by the multi-turn Litz coils at low frequencies, the SNR at 3T was predicted to be a factor of approximately two higher compared to 73.5 mT for both ^{129}Xe and ^{3}He. This compares to a factor of about ten for single-turned copper coils [9]. The experimental values of the SNR measured for ^{129}Xe show reasonable agreement with the theory after correction for differences in sequence parameters and gas polarization. However, for the case of ^{3}He at 73.5 mT, the improvement of the Litz was not as high as expected through theory because the Litz wire used in this work was not optimized for this frequency [4].

Conclusion

The use of multi-turn Litz wire coils for low field strength HNG MRI of rat lungs results in an improvement in SNR of about a factor of five compared to single-turn conventional copper coils. This significantly reduces the advantage (from factor ten to a factor of two) of using high fields (e.g. 3 T) for HNG imaging of rat lungs.

Acknowledgements

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References

1- Gilbert KM et al. Concepts in MR Part B 33B(3) 2008.
2- Parra-Robles et al. Med. Phys. 32: 2005.
3- Parra-Robles et al. J. Magn. Reson. p. 174, 2005.
4- Dominguez et al Proc ISMRM 17, p. 4748, 2009.
5- Kraayvanger et al Proc ISMRM 16, p. 396, 2008.
6- Kraayvanger et all 4th Intern. Workshop on Pulmonary Funct. Imag. 2009
7- Dominguez et al. Concepts in MR Part B, 33B(2), 2008.
8- Dominguez et al Proc ISMRM 17, 2009.
9- Parra-Robles et al Proc ISMRM 14, 2006.

	SNR ratio 3T/73.5mT		Corrected Image SNR	
	Expected	Measured	73.5 mT	3 T
^{129}Xe	2.3	2.6	36.6 ± 1.5	95.2 ± 4.1
^{3}He	2	4.3	76.2 ± 4.3	328.8 ± 7.1

Table 1. SNR comparison of *in vivo* rat lung imaging using ^{129}Xe and ^{3}He at 73.5 mT (using Litz wire) and 3 T.

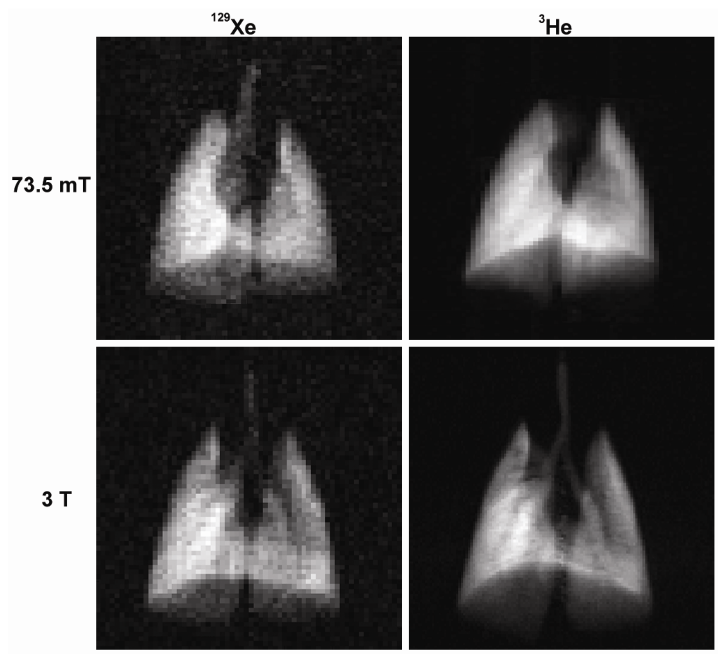

Fig 1. Hyperpolarized ^{129}Xe (left) and ^{3}He (right) images in rat lungs at 73.5 mT (top) and 3 T (bottom). SNR values are compared in Table 1.