T2* Mapping of Hyperpolarized 3He in the Rat Lung using a 3D Cones Imaging Strategy

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Introduction

The 3D Cones sequence [1] utilizes a central-out k-space trajectory that does not require field gradients prior to data sampling. This characteristic can reduce unwanted diffusion weighting, particularly problematic for hyperpolarized ^{3}He gas imaging in small animals. The 3D Cones technique also has the advantages of enabling short echo times (less than 100us), providing an efficient, uniform, 3D sampling density. Furthermore, the short TE capability of the 3D Cones provides a desirable method for acquiring T_2^* maps. Changes in T_2^* values of ^{3}He in the lungs, similar to the apparent diffusion coefficient (ADC), may be sensitive to lung disease and of fundamental importance in the optimization of imaging strategies [2]. This work presents the application of a 3D Cones sequence for lung volume assessment and T_2^* mapping of hyperpolarized ^{3}He gas in the rat lung.

Methods

MR imaging was performed at 3T (Excite 12.x, GEHC) corresponding to a ^{3}He Larmor frequency of 97.32 MHz. Hyperpolarized ^{3}He (polarization ~ 35%) was provided by a turn-key spin-exchange polarizing system (HeliSpin™, GEHC). The gas was administered to the rats using a custom ventilator, which included a non-metallic valve assembly for delivery of ^{3}He within the MR environment with minimal depolarization. MR imaging was performed on Sprague Dawley rats (400–450 g) following an approved institutional animal care protocol. A 3D Cones imaging sequence [3] was adapted for imaging of hyperpolarized ^{3}He. In-vivo rat lung images were acquired with a 2 ms read-out window. For lung volume measurement, TE = 0.1 ms, TR = 4.5 ms and FOV = 5 cm. For 2 mm isotropic resolution, the total scan time was 2 to 3 seconds depending on acquisition window width and extra acquisition points for gradient delay correction. For 1mm resolution, the total scan time was 9 seconds. A variable flip angle (VFA) acquisition method was used [4] to account for the non-recoverable nature of the hyperpolarized signal. For T_2^* mapping, the 3D Cones sequence was configured in 2-echo mode with TE1 = 120□s, TE2 = 5ms and TR = 10ms with a total scan time of 9 seconds. Two sets of 3D images were reconstructed and T_2^* was obtained from single exponential fitting on a pixel-by-pixel basis to generate T_2^* maps and histogram.

Results and Discussion

Figure 1 shows a typical in-vivo 3D cones ^{3}He image of rat lung. Due to the efficient 3D sampling of data provided by the 3D Cones acquisition, a volume with excellent coverage and acceptable, isotropic spatial resolution was acquired in the 2-3 s breath-hold interval. The isotropic data allows visualization of the lung volume in any orientation without loss in resolution. This will be useful for thorough evaluations of the complex geometry of the lungs and accurate measurement of the lung volume. The upper airway of the lung was clearly observed as expected due to the minimal diffusion weight. Figure 2 shows multiple slice T_2^* maps and the corresponding T_2^* histogram of the hyperpolarized ^{3}He gas in an in-vivo rat lung.

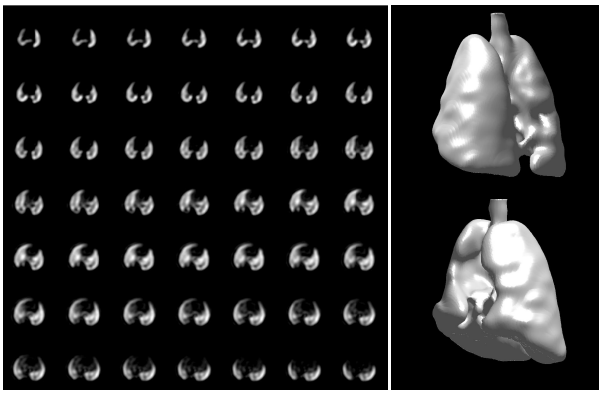
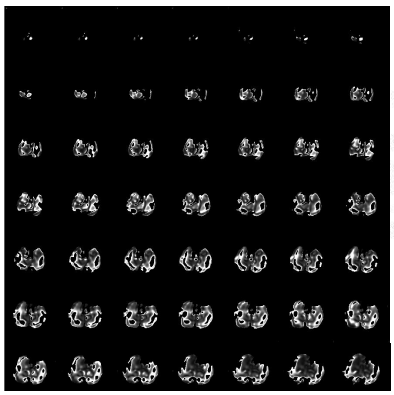


Figure 1, Image of the hyperpolarized ^{3}He gas in an in-vivo rat lung in axial view (left) and the rounded lung (right).

The T_2^* histogram (Fig. 2) reveals a wide distribution of values (from 1ms to tens of ms) across the rat lung, presumably due to the range of apparent diffusion coefficients (ADC) and susceptibility differences for ^{3}He in the lung, both of which are expected to significantly affect T_2*. This may suggest that T_2* maybe useful for characterizing lung disease (e.g. Emphysema) in a manner similar to ADC.

Our preliminary T_2* measurements suggest that 3D Cones is a promising tool for clinic studies. For clinical study increasing of voxel size (up to 4 mm) would permit us to sample T_2^* decay better by collecting more than two echoes during one breath hold.



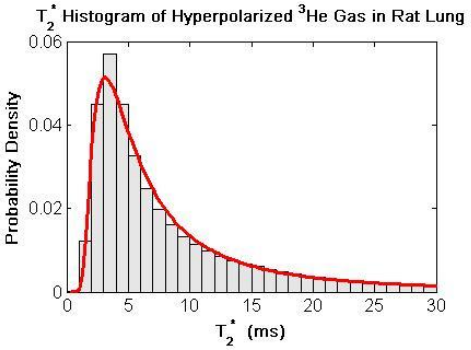


Figure 2, Left: 3D T_2^* map shown in axial view; Right: T_2^* histogram (grey bar) with the 'extreme value distribution' fitting (red line).

References

[1] PT Gurney et al., MRM, 2006, 55(3): 575-582; [2] J Parra-Robles et all., JMR, 2008, 192: 85-91; [3] JA Stainsby et al., ISMRM 2007, 1331; [4] G Santyr et all., MRM 2008, 59:1304–1310