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 3He 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 T2 maps. Changes in T2 values of 3He 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 T2 mapping of hyperpolarized 3He gas in the rat lung.

Methods:
MR imaging was performed at 3T (Excite 12.x, GEHC) corresponding to a 3He Larmor frequency of 97.32 MHz. Hyperpolarized 3He (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 3He 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 3He. 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 T2 mapping, the 3D Cones sequence was configured in 2-echo mode with TE1 = 120 ms, TE2 = 5ms and TR = 10ms with a total scan time of 9 seconds. Two sets of 3D images were reconstructed and T2 was obtained from single exponential fitting on a pixel-by-pixel basis to generate T2 maps and histogram.

Results and Discussion:
Figure 1 shows a typical in-vivo 3D cones 3He 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 T2 maps and the corresponding T2 histogram of the hyperpolarized 3He gas in an in-vivo rat lung.

The T2 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 3He in the lung, both of which are expected to significantly affect T2*. This may suggest that T2* maybe useful for characterizing lung disease (e.g. Emphysema) in a manner similar to ADC.

Our preliminary T2* 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 T2* decay better by collecting more than two echoes during one breath hold.

References:

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

Figure 2, Left: 3D T2* map shown in axial view; Right: T2* histogram (grey bar) with the ‘extreme value distribution’ fitting (red line).