Measuring the 3He Long Range ADC using a Slice Washout Method

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Introduction

Pulsed-gradient-spin-echo experiments (PGSE) of ^{3}He diffusion in the healthy lungs reveal an apparent diffusion coefficient (ADC) of approximately 0.2 cm^2s^{-1}. Usually, such experiments are conducted with small diffusion times (~2 ms), which means they are only sensitive to diffusion on short length scales (~ 0.6 mm). We present an alternative method for measuring "long-range" restricted diffusion, where we exploit the fact that diffusion acts to "washout" the slice profile of a 2D image (Figure 1). This, in turn, affects the pixel signal evolution from a time-series of images, that are acquired from the same slice location. In the absence of diffusion, the signal evolution is exponential because the magnetisation is non-renewable. Diffusion causes a deviation in the signal decay. Hence with a suitable analysis we can deduce the ADC value. We used finite-difference methods to simulate the longitudinal magnetisation in 1D [1], which allowed us to calculate the long range ADC value.

Methods

Five healthy volunteers of various ages were assessed. Work was also carried out in vitro within a hollow cylindrical vessel. **In vitro MR images:** 2 FLASH data-sets were acquired; images = 10, flip-angle = 5.1^0, Ny = 100, TR = 11 ms, delay between images = 150 ms. First data-set acquired with no slice selection, second with a 13.1 mm slice. **In vivo FLASH MR images:** It was important to determine T1 and flip-angle, therefore three image sets were acquired. **1) "T1-Image":** $\approx 0.5^0$ flip angle, 6 ms TR, 2.5 ms TE, 20 phase encodes, 42 cm FOV, 60 mm slice, 10 images acquired. **2) "Low-flip Image":** 5^0 (nominated) flip angle, 11 ms TR, 8.0 ms TE, 42 cm FOV, 64 phase encodes, 13.1 mm slice thickness, 10 images acquired at 0.8 second intervals from same slice location. **3) "Hi-flip Image":** Same as previous, but flip-angle exactly twice as large, 10^0 (nominated). The data from the "low-flip" and "high-flip" images were simultaneously fitted using a least-squares method, which was driven by 1D finite-difference simulations.

Results

In vitro results are shown in Figure 2. The simulated data is an almost perfect fit to the experimental data and was considered a validation of the method. An example from one volunteer is shown in Figure 3. Again, the in vivo experimental results fit the simulation trend well. The average ADC over all volunteers was 0.033 cm^2s^{-1}, which is much lower than PGSE measurements.

Discussion

We have demonstrated a method for determining the "long range" diffusion coefficient in the lungs. The values are much smaller than those obtained with PGSE methods and are close to the values obtained by the tagging experiments performed by Woods et al and Owers-Bradley et al [2-3]. The small ADC value suggests that the gas must undertaken a "long" and tortuous path between neighbouring alveoli.

References

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2. Owers-Bradley JR, et al. *MR tagging of human lungs using hyperpolarized 3He gas*. J Magn Reson Imag, 2003. **17**: pp. 142-6.
3. Woods JC, et al. *Magnetization Tagging Decay to Measure Long-Range 3He Diffusion in Healthy and Emphysematous Canine Lungs.* Magn Reson Med, 2004. **51**: pp. 1002–1008.

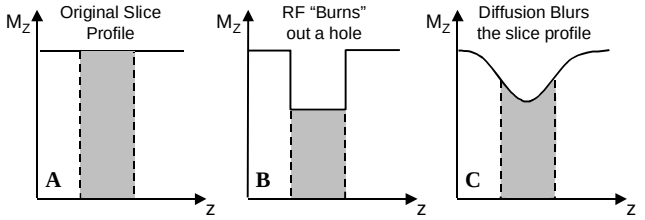

Figure 1: The effect of diffusion on the slice profile. Diffusion acts to "top up" the magnetisation within the slice bounds after RF pulse.

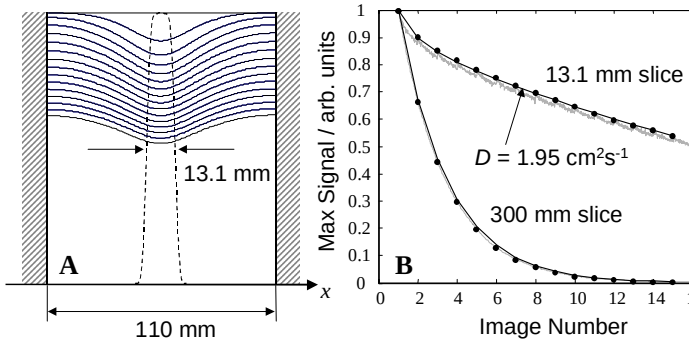

Figure 2: In vitro results against theory for a hollow cylindrical sample, images were acquired at 1.25 s intervals a) The magnetisation profile at the start of each image, as calculated by the finite-difference method. The flip-angle profile, α, is also shown. b) The in vitro result displayed against theory, with $D_0 = 1.95$ cm^2s^{-1}. The grey line is the amplitude of each FID. The data is in excellent agreement with the simulation results

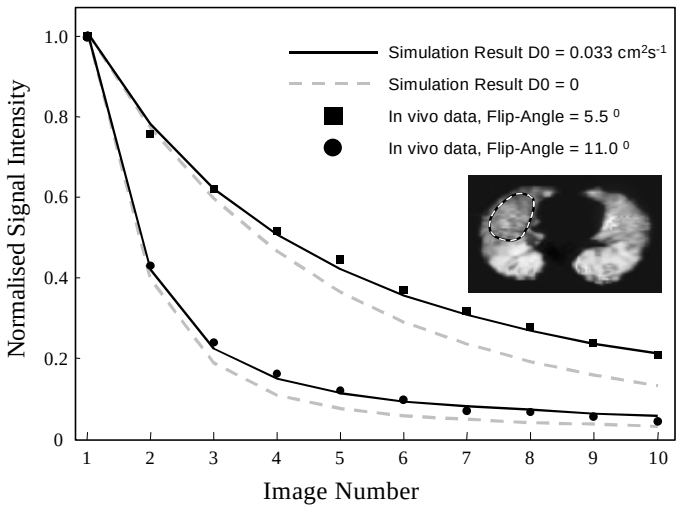

Figure 3: In vivo data, each image acquired at 1.25 second intervals. The data was analyzed using a T_1 value of 25 seconds. The effect of diffusion is clearly evident when the data is compared to the gray-dashed line, plotted for $D_0 = 0$.