DIFFUSION AND TAGGING OF HYPERPOLARISED ^{3}HE IN THE LUNGS

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Introduction

Tagged MR images have been used as a means of measuring cardiac motion for some years. We show that we can use a similar method to measure respiratory motion in the lungs by tagging the magnetisation of hyperpolarised ^{3}He (see below). We also use the decay rate of the "tags" to measure the apparent diffusion of He in the lungs. We find that the "tags" persist for a longer time than we had expected, based on previous ADC measurements in the lungs which give values of 0.2 cm^2 s^{-1}.[1] In order to investigate this further we have undertaken a study of diffusion using both spin echoes and tagging over length scales ranging from 2 mm to 50 mm.

Spin Echo Attenuation

The attenuation of spin echoes is used to measure the ADC. We follow the decay of a RARE echo train.. Shown below are the relaxation rates for He-3/He-4 in the lungs and in free space using a RARE echo train. Note the values for D in the bag and for the ADC in the lungs are different by a factor 10 where D=1.8cm^{2}s^{-1}.

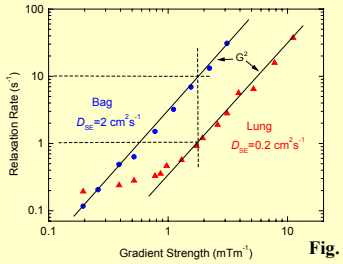


Fig. 3

Method

The hyperpolarised ^{3}He gas for this study was produced by metastable pumping using a 2 W fibre laser (Keopsys, France) and a peristaltic compressor, described elsewhere in this conference (Fichele *et al*). Samples of gas containing 50 cm^3 of ^{3}He at around 15% polarisation could be collected in about 30 minutes. ^{4}He was used to dilute the ^{3}He gas to increase the volume to 1 litre prior to inhalation. The images were generated using a 0.15 T scanner.

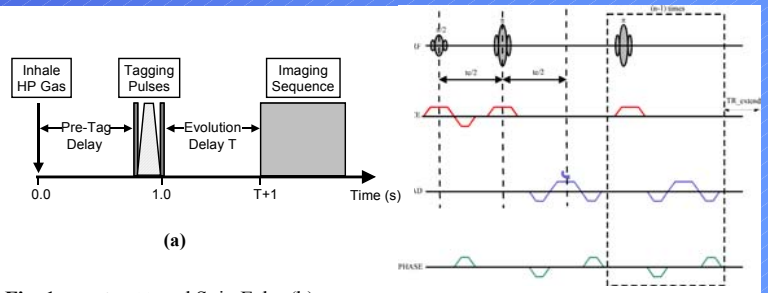


Fig. 1. Tagging (a) and Spin Echo (b) sequences

Diffusion Regimes

There are 3 regimes for gas diffusion depending on the relative size of the pores a, the gradient G and the gas diffusion coefficient D.. For a simple echo sequence as shown in Fig. 4, the attenuation in each regime is[2]:

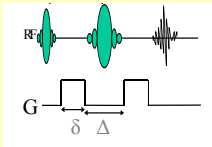


Fig. 4

Free Diffusion $\Delta D << a^2 \rightarrow \exp\{-\gamma^2 G^2 \delta^2 D(\Delta - \delta/3)\}$

Restricted Diffusion $D << a^2$ and $\delta D << a^2 \rightarrow \exp\{-a^2\gamma^2 G^2 \delta^2\}$

Rapid Diffusion $\delta D >> a^2 \rightarrow \exp\{-a^4\gamma^2 G^2 \delta / D\}$

Fig. 5 shows a random walk simulation of the spin-echo attenuation illustrating how the ADC value varies with alveolar dimension, a, for a fixed D of 1 cm^{2}s^{-1}. The expected a^4 dependence is seen in the rapid diffusion limit

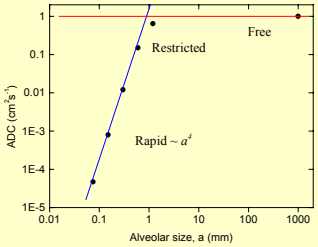
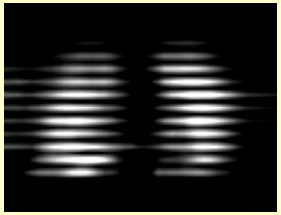


Fig. 5



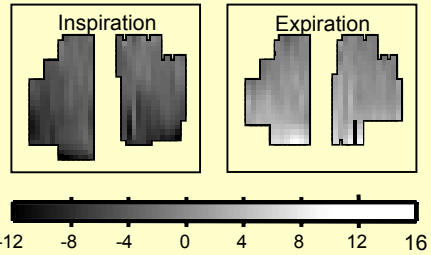


Fig. 2 Tagged Image of the lungs with ^{3}He (64x64, FOV=350mm) and measured strain in the lungs.

Tag Decays

For a range of tag wavelengths we have followed the decay of the tags by generating profiles using small rf tipping pulses. For a tag wavelength $\lambda=2\pi/k$ the magnetisation follows a cos(kz) profile and the exponential decay rate is given by $-k^2D$. Hence we plot the decay rate in the lung as a function of k^2. The slope is the ADC and is 0.02 cm^{2}s^{-1}.

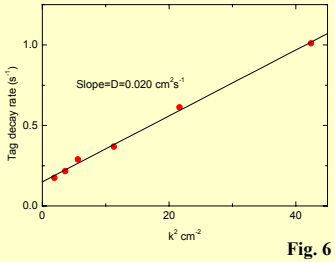


Fig. 6

Discussion

It is clear that the two methods for evaluating the ADC yield very different values. As we note above, the relationship between the ADC extracted from the spin echo method and the lung structure depends on the diffusion regime. For typical HP gas imaging, we believe that the relevant regime is between restricted and rapid diffusion. The tagging method is in some ways easier to interpret. It measures the diffusion of the ^{3}He over length scales, 10-50mm. The results may be helpful in developing developing models of the lung structure and understanding the effect of disease.

References

1. BT Saam, DA Yablonsky, VD Kodibagkar, JC Leawoods, DS Gierada, JD Cooper, SS Lefrak, MS Conradi , *Magn. Reson. Med.* **44**, 174 (2000).

2. E Fukushima, NMR Newletter 431, p51 (1994).