Influence of inspiration level on hyperpolarized ^{3}He ADC in healthy lungs

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Introduction: The size of the alveolar airspaces of the lung can be probed by diffusion measurements using hyperpolarized gases. It has been shown that there is a direct correlation between the alveolar size and the calculated apparent diffusion coefficient (ADC) [1]. Lung diseases as e.g. COPD lead to increased ADC values (e.g. [2,3]) and it is hoped that the diffusivity measure can detect the first small changes in lung microstructure leading to emphysema. Though obvious, the ADC dependence on inspiration level has not been studied in much detail previously. In this preliminary study the changes in global and regional ADC values as a function of inspiration level are investigated.

Methods: Three lung healthy volunteers were imaged with hyperpolarized ^{3}He MRI. The ^{3}He gas was polarized in Mainz, Germany and shipped to Copenhagen by air transport [4]. A Siemens Vision scanner 1.5 T equipped with a ^{3}He/^{1}H birdcage coil (Fraunhofer Institute, St. Ingbert, Germany) was used for imaging the subjects in supine position. Diffusion measurements were carried out during a 12 s breathhold using a 2D FLASH sequence with a bipolar gradient (TR/TE 16.1ms/6.0ms, $\alpha<10^o$, FOV 470 mm, slice thickness 20 mm, matrix 64x128, diffusion gradient 12mT/m, b=3.89s/cm^2). Four images (no diffusion weighting and diffusion weighting along three orthogonal directions) for each of three axial slices (3 cm above, at the level of and 5 cm below carina) were acquired after inhalation of approx. 250 ml hyperpolarized ^{3}He in four levels of inspiration: maximum expiration, small, medium and maximum inspiration. The total inspired gas volume (starting from maximum expiration) was measured by the computer-controlled gas applicator [5]. The ADC maps were calculated by an in-house developed Matlab® program. Each slice was divided into two regions of interest covering the anterior and the posterior part, respectively (Figure 1). A fractional inspiration volume was determined for each intermediate inspiration level as the ratio between the total inspired gas volume and the inspired volume determined at maximum inspiration.

Results: ADC mean values in expiration and inspiration for each of the subjects were calculated for the anterior and posterior parts (averaged over the three slices) as well as for each slice (denoted apical, carina, basal) and are presented in Table 1.

Subject	Anterior	Posterior	Apical	Carina	Basal
A	0.13 / 0.18	0.11 / 0.18	0.12 / 0.18	0.12 / 0.18	0.12 / 0.18
B	0.13 / 0.16	0.12 / 0.16	0.14 / 0.17	0.12 / 0.16	0.11 / 0.15
C	0.13 / 0.15	0.12 / 0.16	0.13 / 0.16	0.13 / 0.15	0.12 / 0.15

Table 1 Expiration/inspiration mean ADC values in cm^2/s.

The ADC value as function of the fractional inspiration volume for anterior and posterior parts is shown in Figure 2.

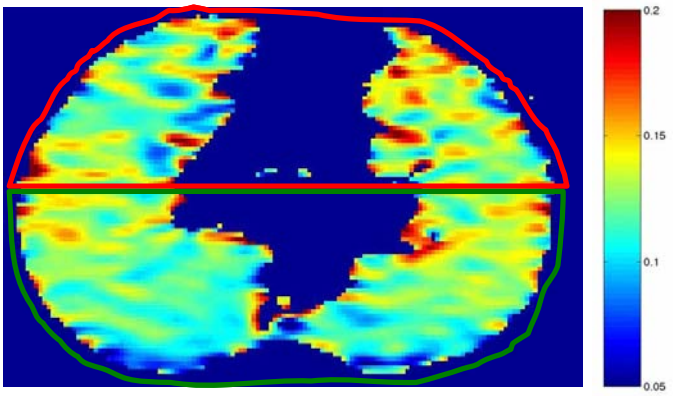

Figure 1 Expiration ADC map (cm^2/s) with anterior (red) and posterior (green) regions of interest.

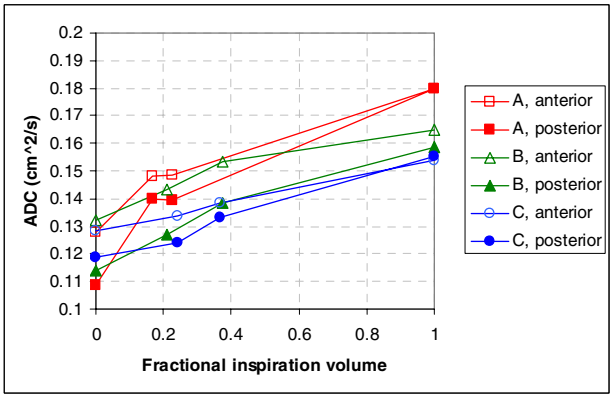

Figure 2 ADC as function of the fractional inspiration volume (0: maximum expiration, 1: maximum inspiration).

Discussion: For all three subjects the mean ADC in inspiration is larger than in expiration for all regions (Table 1). The anterior-posterior difference with the lowest ADC values in the posterior, most dependent part [6] seems most pronounced in expiration. The ADC grows monotonically with the fractional inspiration volume (Figure 1). Though the inspiration level was not measured spirometrically in this study it clearly indicates that the ADC depends strongly on the inspired volume. These results show that if the ADC measure is going to be used to detect small micro-structural changes in order to e.g. diagnose early emphysema or monitor treatment response, it is very important not only to compare the same spatial area but also make sure that the inspiration status of the subject is well controlled. It remains to be seen how the inspiration level affects the ADC in patients and whether new information can be extracted from the expiration ADC.

References

[1] Peces-Barba G, Ruiz-Cabello J, Cremillieux Y et al., Eur Respir J 2003;22:14-19
[2] Salerno M, de Lange EE, Altes TA et al., Radiology 2002;222:252-260
[3] Stavngaard T, Søgaard LV, Mortensen J et al., Eur J Nucl Med Mol Imaging 2005;32:448-457
[4] Wild JM, Schmiedeskamp J, Paley MNJ et al., Phys.Med.Biol. 2002;47:N185-N190
[5] Aidam E, Ebert M, Grossmann T et al 1997, Patent DE 197 42 548, Germany; Aidam E, Ebert M, Grossmann T et al 1998, Patent PCT/EP 98/07515 and 07516"
[6] Fichele S, Woodhouse N, Swift AJ et al., J Magn Reson Imaging 2004;20:331-335