Effects of application of Positive End Expiratory Pressure on ADC in HP 3He MRI

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Introduction: Hyperpolarized ^{3}He diffusion MRI is a widely used imaging technique for both animal and human lungs, which is able to reveal information about the microstructure. ADC maps -one of the main applications of ^{3}He imaging- have been shown to yield differences between healthy and emphysematous animals (1-4), and also to be sensitive to other pulmonary diseases. Part of these experiments has been performed in vivo under mechanical ventilation (2-4). Among the published works, it is possible to find very diverse ventilation strategies: Chen et al. (2) applied a constant tidal volume of 2 cm^3 to the rats, while, Jacob et al. (4) applied a HP ^{3}He-N_2 mixture of 1 ml followed by 4ml of air to a maximum pressure of 15 mbar. Some studies have been performed concerning ventilator-induced lung injury (VILI) as well. Walder et al. (5) demonstrated the preponderant effect of the duration (>3h) of 'aggressive' ventilation and the cut-off value of the level of tidal volume applied (>27 mL kg^{-1}) in rats.

The goal of the present work is to study the behaviour of ADC as a function of ventilation time at different airway pressure during breath-hold and different positive end expiratory pressure (PEEP).

Methods: An NMR compatible ventilator was used to obtain short range diffusion images with HP ^{3}He at 0.5 Tesla. A radial imaging sequence with four b-values, ranging from 0.05 to 4.26s/cm^2, and a diffusion time of 1.5 ms was used. The gas was polarized at 65-70% by the metastable optical pumping technique (6). In total fifteen Wistar rats were measured, divided in five groups corresponding to different ventilation parameters. Group 1 and 2 were measured at null PEEP, and ventilation pressure of 10 and 25mbar respectively. For the groups 3 and 4 a PEEP of 5 mbar was applied by connecting a water column. Ventilation pressure during the experiment was set to 10mbar for group 3 and 25 mbar for group 4. For the fifth group a breath-hold pressure of 25 mbar and a PEEP of 10 mbar were applied. The respiratory frequency was 60 bpm, with a ratio 1:1 for inspiration + breath-hold: expiration. The acquisition lasted 8 s and the images were acquired during a 10 s breath-hold. Prior to acquisition 3 washes of ^{3}He were applied to remove residual air in the lung as much as possible. All animals were ventilated for 70min, and images were acquired at time points, 10, 25, 40, 55, 70 min. After imaging animals were sacrificed and the lungs were extracted and fixed with formalin.

Results and Discussion: ADC as a function of time at different PEEP and pressure during breath hold is shown in Fig 1. The ADC values were nearly constant over time in every group. This may indicate that lung injury does not occur under those ventilation conditions and ventilation times or that ADC is not sensitive enough for this purpose.
ADC shows to be not strongly dependent on ventilation pressure but on PEEP value, even though a higher ventilation pressure yields a tendency to slightly higher ADC. There are significant differences in ADC between two groups with different PEEP (0-5, 0-10 and 5-10 mbar PEEP) and the same breath-hold pressure but not between the two groups with the same PEEP and different breath-hold pressure (10 and 25 mbar). The effect of finding a lower ADC for higher PEEP may be due to a decrease in concentration of ^{3}He in the lung and therefore a decrease in the free diffusion coefficient. As a consequence of reduction of ^{3}He concentration, a decrease in SNR was also observed, which can contribute to the decrease in measured ADC as well. The deviation of ADC value at PEEP 10 is higher than in the other groups. This is shown in Fig 2, as well as the mean ADC (±SD) for all groups.

Conclusion: No differences in ADC were found over observation time for any PEEP value or ventilation pressure. Animals connected to a water column to increase the PEEP showed a lower ADC probably due to a decrease in He concentration. The influence of alveolar recruitment or gas mixture on the ADC is currently under investigation. Groups measured at different PEEP are significantly different but not those where the PEEP was the same and the breath-hold pressure changed. All these findings emphasize the importance of well defined ventilation parameters in order to make results from different studies comparable.

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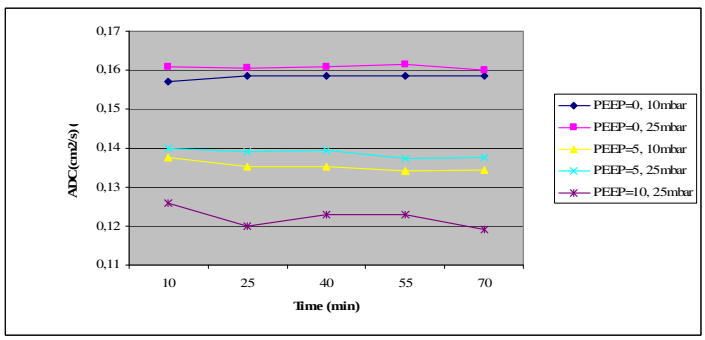

Fig 1

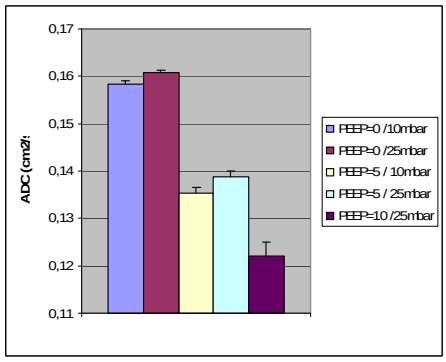

Fig 2