

Detection of Regional Microstructural Changes of the Lung in Emphysema Using Hyperpolarized ^3He Diffusion MRI

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Introduction

Recently, the apparent diffusion coefficient (ADC) of ^3He has been measured in animal models [1] and in humans [2,3,4]. Mugler et al. [2] measured the ADC in healthy volunteers to be between 0.2-0.3 cm²/s. Saam et al. [3] demonstrated an increased ADC in a single emphysema patient. As emphysema is characterized by dilation of distal airways, it is expected that the measured ADC should increase reflecting the severity of the parenchymal pathology. Furthermore, there should be greater heterogeneity in the measured ADC coefficients consistent with the distribution of airway destruction. Hyperpolarized ^3He diffusion MRI may thus provide a tool for quantifying the degree of lung pathology in COPD and aid in the planning for lung-volume reduction surgery.

Methods

Hyperpolarized ^3He MRI scans were performed in four COPD patients and five healthy volunteers using a 1.5T whole body imager (Magnetom Vision, Siemens Medical Systems, Iselin, NJ). The data was collected during a breath hold after the subject inhaled a mixture of 350ml of 20-30% polarized ^3He (Model 9600 Helium Polarizer, Nycomed-Amersham Imaging, Durham, NC) diluted to 1.0 L with ^4He . Diffusion images were obtained using a FLASH pulse sequence (TR/TE 16/6ms, FA 6°, FOV 38x50cm, thickness 10-15mm, matrix 100x256) with additional gradients for diffusion weighting in the readout direction to achieve b-values of 0.4, 0.8, 1.2, and 1.6 s/cm². Between one and three slices were obtained, depending on the subjects' ability to hold their breath (6 seconds/slice). ADC maps were calculated by linear least squares fitting of the natural log of the signal versus the b-value. Histograms were created by grouping the ADC values from each voxel into fifty bins.

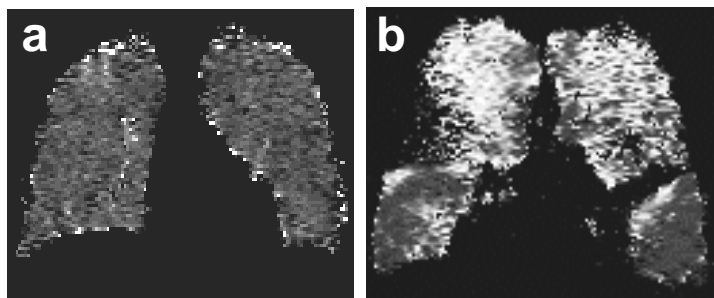


Figure 1: ADC maps from (a) a 63-year-old healthy volunteer and (b) a 69-year-old patient with emphysema.

Results

Representative ADC maps, and the corresponding histograms, from a COPD patient and an age-matched healthy volunteer are shown in Figures 1 and 2, respectively. The mean ADC in the COPD population was significantly higher than that for the healthy volunteers (0.54 ± 0.14 cm²/s compared to 0.23 ± 0.32 cm²/s, $p=0.01$). In addition, the standard deviation (width) of the ADC histogram, which is a measure of heterogeneity, was significantly wider in the COPD population (0.38 ± 0.19 cm²/s versus 0.10 ± 0.02 cm²/s, $p=0.03$). The patient's lungs shown in Figure 1 exhibit regional differences in ADC values as demonstrated in Figure 3. The mean ADC in the upper segments is 0.89 cm²/s (width 0.19), while that in the lower segments is 0.44 cm²/s (width 0.09).

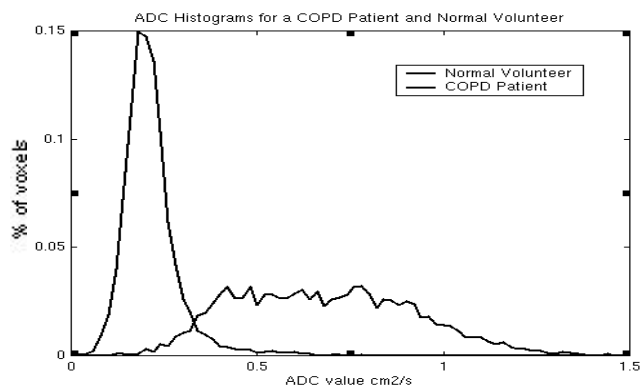


Figure 2: ADC histograms for the healthy volunteer (mean 0.21 cm²/s, standard deviation 0.096 cm²/s) and COPD patient (mean 0.67 cm²/s, standard deviation 0.28 cm²/s) whose ADC maps are shown in Figure 1.

Discussion

The ADC values in the lungs of healthy subjects were fairly uniform, while those in the lungs of COPD patients showed marked heterogeneity. In the patients studied, the ADC values were often much higher at the apices of the lung, which is consistent with the typical distribution of centroacinar emphysema. As the disease progresses, the pathology spreads towards the bases, resulting in ADC values in the bases that are increased relative to that for normal age-matched volunteers. The ADC histograms for the COPD patients were wider and shifted towards higher ADC values compared to healthy subjects.

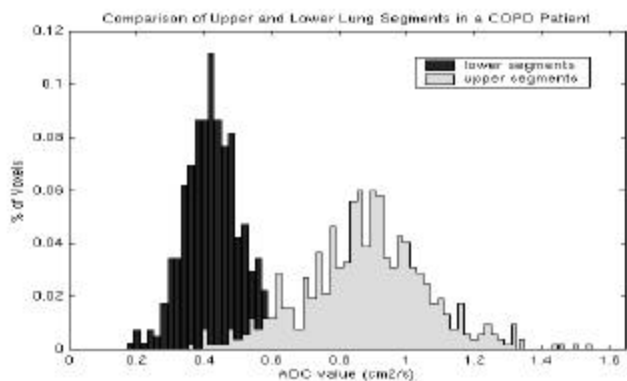


Figure 3: Histograms from the upper (mean 0.89 cm²/s, standard deviation 0.19 cm²/s) and lower (mean 0.44 cm²/s, standard deviation 0.09 cm²/s) lung segments of the COPD patient demonstrate regional differences in ADC values.

Conclusion

These results suggest that hyperpolarized ^3He diffusion MRI is potentially a sensitive technique for the detection of regional and global pathology in emphysema.

References

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