Early Detection of Emphysematous Changes in Smokers using Hyperpolarized ^{3}He MRI

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INTRODUCTION

Emphysema is characterized by breakdown in the alveolar walls of the lungs in smokers. Characterization and diagnosis of chronic obstructive pulmonary disease (COPD) and emphysema relies on spirometry and high resolution computed tomography (HRCT) [1, 2]. Previous studies have shown highly significant increases in apparent diffusion coefficient (ADC) of hyperpolarized ^{3}He in patients with emphysema [3, 4]. The goal of this work is to study the sensitivity of the ADC measure for detecting the early onset of emphysema. The ADC in the lungs of asymptomatic smokers is compared to non-smokers of similar age and gender. In addition the whole lung and regional ADC is compared to spirometry including DLCO, FEV_1, FEV_1/FVC and regional "Emphysema Index" (EI; Relative area of lung parenchyma having signal intensity < -950 Hounsfield units) derived from HRCT.

MATERIALS AND METHODS

Hyperpolarized ^{3}He MR lung ventilation imaging was performed in twenty subjects (eleven smokers and nine non smokers; one study was incomplete due to technical reasons) using a 1.5 T MR scanner with broadband capabilities (Signa LX, GE Medical Systems, Milwaukee, WI). A vest RF coil (IGC-Medical Advances, Milwaukee, WI) tuned to receive at 48.6 MHz was used. A helium polarizer (IGI.9600, Amersham Health) used spin exchange optical pumping to polarize ^{3}He. Each MR session consisted of proton localization and fast spin echo (FSE), followed by ^{3}He flip angle calibration, ventilation, diffusion weighted and dynamic MRI scans to detect ventilation defects, breakdown in alveolar space and gas trapping respectively. For ventilation and diffusion-weighted scanning a spoiled GRE sequence was used with the following parameters ±15.63 KHz BW, 128 x 128 matrix, FOV (32-38) cm x (24-29) cm, and ten 1.5 cm thick slices. A 1-liter dose of hyperpolarized ^{3}He with a net activity of 4.5 mMol was inhaled for each ^{3}He scan. Images were acquired during breath holds of up to approximately 15 seconds. Diffusion gradients were added to the slice encoding axis (anterior/posterior direction) and phase encoded views were acquired alternately with and without diffusion weighting in an interleaved order. ECG and oxygen saturation (saO_2) were monitored throughout the imaging session. Regional analysis was performed by segmenting the lung parenchyma in the ADC maps into the apical, middle and basal region for the right and the left lungs (based on high resolution CT; Figure1).

RESULTS AND CONCLUSIONS

Our results show ADC to be a sensitive indicator of early onset of emphysema (Table 1, 2). A statistically significant correlation was observed between mean ADC and number of pack years (r_s=0.74, p≤0.0001; Table 1, Figure 2 (a)). This relationship remained significant after adjusting for age (p=0.0060). Negative correlations of mean ADC with percent predicted diffusion lung carbon monoxide (DLCO) (r_s=-0.82, p≤0.0002) (Figure 2 (b)) and FEV_1/FVC (r_s=-0.70, p ≤ 0.0008) were observed. It is important to note that FEV_1 % predicted showed no significant relationship with pack years in this data. Strong correlations between ADC mean and pack years by region were observed with stronger dependence in the apical vs. basal region. No statistical significance was observed between EI and pack years based on region. The dependence of mean ADC on DLCO was expected given that the surface area for gas exchange into the blood stream is reduced in emphysema. Our results indicate mean ADC is a sensitive measure of early changes in lung micro-structure in asymptomatic smokers.

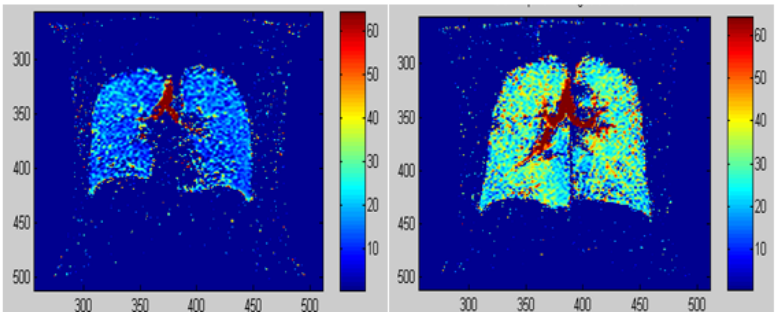

Figure 1: (a) ADC map of non smoking control: ADC 0.178 cm^2/s (pink box in Figure 2(a)) and (b) ADC map of smoker: ADC 0.289 cm^2/s (maroon box in Figure 2(a)). Color bar units: mm^2/s.

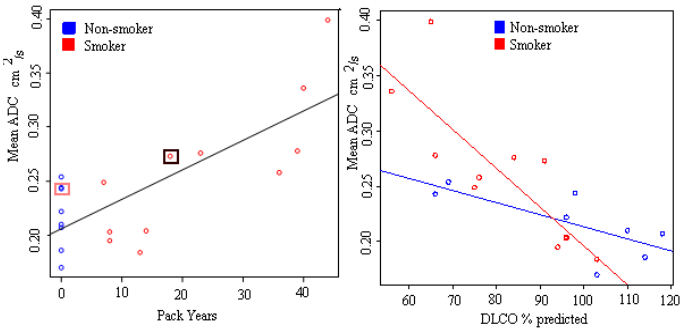

Figure 2: Plots of (a) Pack Years vs. ADC Mean (b) ADC Mean vs. DLCO % predicted.

Table 1: Whole lung comparisons.

Independent Variable	ADC Mean (correlation coefficient, r_s)	P - value
FEV_1 %p	- 0.36	P ≤ 0.13
FEV_1/FVC	- 0.70	P≤ 0.0008
DLCO %p	- 0.82	P≤ 0.0002
Pack Years	+ 0.74	P≤ 0.0001
Age+Pack Years	+ 0.80	P≤ 0.0007

Table 2: Comparisons of ADC Mean and Emphysema Index dependence on pack years by region.

Region	ADC Mean (Spearman's rho)				Emphysema Index (Spearman's rho)			
	Left	p-value	Right	P-value	Left	p-value	Right	p-value
Apical	0.68	0.0020	0.61	0.0061	- 0.13	0.61	- 0.15	0.56
Middle	0.61	0.0066	0.60	0.0076	- 0.46	0.058	- 0.44	0.069
Basal	0.56	0.0131	0.55	0.0154	- 0.28	0.26	- 0.31	0.21

REFERENCES

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