

Wash-in Time of Molecular Oxygen from Dynamic Oxygen-enhanced MRI: New Approach for Assessment of Smoking-related Pulmonary Functional Loss

Y. Ohno¹, H. Koyama¹, M. Nogami¹, M. Obara², H. Kawamitsu³, D. Takenaka¹, M. V. Cauteren², H. Hatabu⁴, K. Sugimura¹

¹Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, ²Philips Medical Systems, Tokyo, Japan, ³Division of Radiology, Kobe University Hospital, Kobe, Hyogo, Japan, ⁴Radiology, Beth Israel Deconess Medical Center, Boston, MA, United States

Introduction: Cigarette smoking is the most important risk factor of chronic obstructive pulmonary disease (COPD). Several investigators try to evaluate the functional loss due to cigarette smoke by CT, although CT can only demonstrate the regional structural change. Oxygen-enhanced MR imaging offers an alternative approach for assessment of regional pulmonary function (1, 2). In addition, some investigators suggested the possibility of dynamic oxygen-enhanced MR imaging for assessment of wash-in time of oxygen by respiration (3-5).

We hypothesized that wash-in time of molecular oxygen from dynamic oxygen-enhanced MR data may have a potential to be a more sensitive parameter for assessment of smoking-related air-way dependent pulmonary functional loss, when compared with regional oxygen-enhancement. The purpose of the present study is to determine the capability of was-in time of molecular oxygen from dynamic oxygen-enhanced MR data for assessment of smoking-related pulmonary functional loss, as compared with regional oxygen-enhancement.

Method and Materials: 12 healthy non-smoking volunteers (8 men and 4 women; age range 23-81 years) and 48 consecutive smokers (38 men and 10 women; age rang 21-82 years) underwent dynamic oxygen-enhanced MR imaging, multi-slice CT, and measurements of forced expiratory volume in 1 second (FEV₁%) and diffusing capacity of the lung (DL_{CO}/V_A). All oxygen-enhanced MR imaging were performed with a centrally-reordered inversion recovery single shot turbo spin echo sequence (TE 4 ms/ TI 900 ms/ echo spacing 4 ms, 3 slices) using a 1.5T whole body scanner (Gyrosan Intera, Philips Medical Systems, Best, The Netherlands).

From signal intensity-time course curve of dynamic oxygen-enhanced MR data in each subject, regional relative enhancement ratio and wash-in time of molecular oxygen maps were generated by pixel analyses. Then, overall oxygen-enhancement and mean wash-in time in each subject was determined as the average of regional oxygen-enhancements and wash-in times in 6 spatially defined regions of interest (ROIs) in both lungs on three coronal planes (total 18 ROIs). From density-masked CT, degree of smoking-related pulmonary emphysema in each subject was calculated as the percentage of low attenuation area in the entire lung (%LAA) by using a commercially available soft ware.

To assess the difference between normal subjects and smoking-related COPD subjects, overall oxygen-enhancement and mean wash-in time were compared by Student's t-test. To determine the capability for assessment of smoking-related pulmonary functional loss, overall oxygen-enhancement and mean wash-in time were correlated with Brinkman's index, %LAA, FEV₁% and DL_{CO}/V_A. A p value less than 0.05 was considered as significant in each statistical analysis

Results: All 60 dynamic oxygen-enhanced MR imaging examinations were completed successfully. No adverse effects were observed. Representative cases are shown in Figure 1, 2 and 3.

On comparison of overall oxygen-enhancement and mean wash-in time, overall oxygen-enhancement had significant difference between normal (0.13 ± 0.04, Mean ± Standard deviation) and smoking-related COPD (0.08±0.03) subjects (p<0.05). Mean wash-in time also demonstrated significant difference between normal (19.5 ± 6.0 sec, Mean±Standard deviation) and smoking-related COPD (28.0 ± 9.8 sec) subjects (p<0.05).

The results of correlation with Brinkman index, %LAA, FEV₁% and DL_{CO}/V_A are shown in Table 1. Overall oxygen-enhancement had moderate negative correlation with Brinkman's index and %LAA (p<0.05), and had good positive correlation with FEV₁% and DL_{CO}/V_A (p<0.05). Mean wash-in time had moderate positive correlation with Brinkman's index and fair positive correlation with %LAA (p<0.05). In addition, mean wash-in time had excellent negative correlation with FEV₁% and good negative correlation with DL_{CO}/V_A (p<0.05).

Conclusion: Wash-in time of molecular oxygen from dynamic oxygen-enhanced MR data can assess smoking-related pulmonary functional loss similar to regional oxygen-enhancement. In addition, wash-in time of molecular oxygen may be more sensitive parameter for assessment of air-way dependent pulmonary functional loss, when compared with regional oxygen-enhancement.

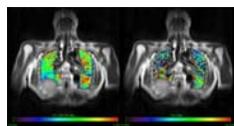


Fig. 1a Fig. 1b

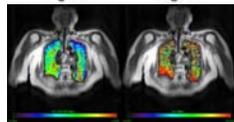


Fig. 2a Fig. 2b

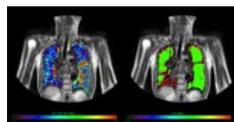


Fig. 3a Fig. 3b

Figure 1. 45-year old non-smoking subject (FEV₁% = 85.0 %, DL_{CO}/V_A = 2.6).

a: Regional oxygen-enhancement map demonstrated high oxygen-enhancement in both lungs. Overall oxygen-enhancement was 0.15. b: Wash-in time map demonstrated regional difference of wash-in time in both lungs. Mean wash-in time was 18.3 sec.

Figure 2. 48-year old smoking subject (Brinkman's index = 250, FEV₁% = 72.5 %, DL_{CO}/V_A = 2.0)

a: Regional oxygen-enhancement map demonstrated slightly decreased oxygen-enhancement in both lungs. Overall oxygen-enhancement was 0.11. b: Wash-in time map demonstrated prolonged wash-in time in both lungs. Mean wash-in time was 26.0 sec.

Figure 3. 65-year old smoking subject (Brinkman's index = 1125, FEV₁% = 34.8 %, DL_{CO}/V_A = 1.3)

a: Regional oxygen-enhancement map demonstrated markedly decreased oxygen-enhancement in both lungs. Overall oxygen-enhancement was 0.07. b: Wash-in time map demonstrated markedly prolonged wash-in time in both lungs. Mean wash-in time was 42.0 sec.

Table 1. Correlation coefficients of both MR parameters.

		r	p value
Brinkman's index	Overall oxygen-enhancement	-0.34	0.0106
	Mean wash-in time	0.41	0.0015
FEV₁%	Overall oxygen-enhancement	0.53	< 0.0001
	Mean wash-in time	-0.64	< 0.0001
DL_{CO}/V_A	Overall oxygen-enhancement	0.54	< 0.0001
	Mean wash-in time	-0.48	0.0002
%LAA	Overall oxygen-enhancement	-0.38	0.0038
	Mean wash-in time	0.29	0.0293

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