

Oxygen-enhanced MR Imaging vs. Density-masked CT: Assessment of Functional Loss Due to Smoking-related Chronic Obstructive Pulmonary Disease (COPD)

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Synopsis: 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 morphological change in lung parenchyma. Oxygen-enhanced MR imaging offers an alternative approach for assessment of regional pulmonary function [1, 2]. We hypothesized that oxygen-enhanced MR imaging may have a potential for assessment of the lung functional loss due to cigarette smoke, when compared with density-masked CT (quantitative CT). The purpose of the present study is to demonstrate the capability of oxygen-enhanced MR imaging for assessment of smoking-related COPD.

Method and Materials: 12 healthy non-smoking volunteers (8 men and 4 women; age range 21-48 years) and 50 consecutive smokers (38 men and 12 women; age range 21-82 years) underwent contrast-enhanced multidetector-row CT, forced expiratory volume in 1 second (FEV1%), diffusing capacity of the lung (%DLco) and oxygen-enhanced MR imaging. All oxygen-enhanced MR imaging were performed with a respiratory synchronized inversion recovery single shot turbo spin echo sequence (TE 4 ms/ TI 900 ms/ echo spacing 4 ms) using a 1.5T whole body scanner (Gyrosan Intera, Philips Medical Systems, Best, The Netherlands). From the oxygen-enhanced MR images, overall oxygen-enhancement in each subject was determined as the average of oxygen-enhancements in 6 spatially defined regions of interest (ROIs) in both lungs on three coronal planes (total 18 ROIs). From quantitative CT images, degree of smoking-related COPD in each subject was calculated as the percentage of low attenuation area in the entire lung (%LAA) by using the commercially available soft ware "Pulmo" produced by Siemens Medical Systems (Forchheim, Germany).

To comparison of the sensitivity of the effect of cigarette smoke between quantitative CT and oxygen-enhanced MR imaging, overall oxygen-enhancements and %LAA of non-smoking subjects (n=12) were also compared with those of smoking subjects whose Brinkman indexes (BIs) were less than 400 (n=16) and more than or equal to 400 (n=34) by using Turkey's HSD test. To determine the capabilities of oxygen-enhanced MR imaging and quantitative CT for assessment of cigarette smoke induced COPD, overall oxygen-enhancement and %LAA were correlated with FEV₁% and %DL_{co}.

Results: All 62 oxygen-enhanced MR imaging examinations were completed successfully. No adverse effects were observed. Representative cases are shown in Figure 1, 2 and 3.

The results of assessment of cigarette smoke effects for morphological change of COPD in quantitative CT and oxygen-enhanced MR imaging are shown in Table 1. On %LAA, non-smoking and BI<400 groups had significant difference with BI≥400 group (p<0.05). On overall oxygen-enhancement, non-smoking group had significant difference with other groups (p<0.05). In addition, BI<400 group had significant difference with BI≥400 group (p<0.05).

On correlation among parameters of pulmonary function test and %LAA, %LAA had good negative-correlation with FEV₁% ($r=-0.78$, $r^2=0.61$, $p<0.0001$) and %DL_{co} ($r=-0.77$, $r^2=0.59$, $p<0.0001$). On correlation among parameters of pulmonary function test and overall oxygen-enhancement, overall oxygen-enhancement had excellent positive-correlation with FEV₁% ($r=0.87$, $r^2=0.76$, $p<0.0001$) and %DL_{co} ($r=0.88$, $r^2=0.77$, $p<0.0001$).

Conclusion: Oxygen-enhanced MR imaging may have a potential for assessment of the lung functional loss due to cigarette smoke, when compared with density-masked CT (quantitative CT). Oxygen-enhanced MR imaging is useful for assessment of smoking-related COPD.



Figure 1. 45-year old non-smoking male subject.

(L to R: CT, quantitative CT, and O₂-enhanced MRI)
Bilateral lungs demonstrate no LAAs on quantitative CT, and homogeneous and high O₂-enhancement.



Figure 2. 48-year old male with BI 200.

(L to R: CT, quantitative CT, and O₂-enhanced MRI)
Bilateral lungs demonstrate no LAAs on quantitative CT, and decreased O₂-enhancement.



Figure 3. 67-year old male with BI 840.

(L to R: CT, quantitative CT, and O₂-enhanced MRI)
Bilateral lungs demonstrate multiple LAAs on quantitative CT, and low O₂-enhancement.

Table 1. The results of assessment of cigarette smoke effects in quantitative CT and oxygen-enhanced MR imaging

| | %LAA (%) | Overall oxygen-enhancement (%) |
|-------------------|------------|--------------------------------|
| | Mean±SD | Mean±SD |
| Non-smoking group | 14±5 | 30±5 |
| BI < 400 group | 17±8 | 24±5* |
| BI ≥ 400 group | 55±20*, ** | 15±6*, ** |

*: Significant difference with non-smoking subjects (p<0.05)

**: Significant difference with BI<400 group (p<0.05)

References:

1. Ohno Y, et al. AJR Am J Roentgenol. 2001; 177: 185-194.
2. Ohno Y, et al. Magn Reson Med. 2002; 47: 1139-1144