

# Dynamic O<sub>2</sub>-Enhanced MRI vs. Quantitative Thin-Section MDCT: Capability for COPD Assessment in Smokers

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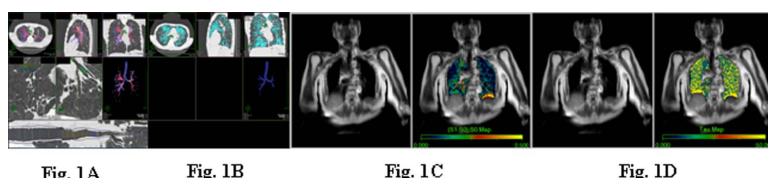
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**Introduction:** Chronic obstructive pulmonary disease (COPD) is currently the fourth-leading cause of mortality and the twelfth-leading cause of disability, and by the year 2020 it is expected to be the third-leading cause of death and the fifth-leading cause of disability worldwide (1, 2). The diagnosis of COPD largely relies on a history of exposure to noxious stimuli (mainly cigarette smoke) and abnormal lung function test results. Recently, oxygen-enhanced MR imaging (O<sub>2</sub>-enhanced MRI) as well as hyperpolarized noble gas MR imaging have been proposed as useful procedures for assessment of regional morphological and functional changes in COPD and other pulmonary diseases (3-8). In addition, direct assessment of signal intensity (SI) - time course curve on dynamic O<sub>2</sub>-enhanced have suggested as having potential for airway abnormality and oxygen transfer assessments in smoking-related COPD (8). However, the literature shows no publications dealing with prospective and direct comparison of the capability of quantitatively assessed thin-section MDCT and of dynamic O<sub>2</sub>-enhanced MRI for COPD assessment in smokers. We hypothesized that dynamic O<sub>2</sub>-enhanced MRI may have potential for COPD assessment without radiation exposure, and be considered at least as valuable as quantitative assessment of MDCT (quantitative MDCT) in smokers. The purpose of this study was to prospectively and directly compare the capability for COPD assessment in smokers between dynamic O<sub>2</sub>-enhanced MRI and quantitatively assessed thin-section MDCT.

**Materials and Methods:** A total of 187 smokers (121 men and 65 women; age range: 23-87 years prospectively underwent pulmonary function test (FEV<sub>1</sub>/FVC%, FEV<sub>1</sub>% and %DL<sub>CO</sub>/V<sub>A</sub>), MDCT and dynamic O<sub>2</sub>-enhanced MRI. Lifetime smoking exposures of all subjects were also quantitatively assessed by using "pack years" (range: 3-250 pack years, mean: 67 pack years). Then, 52 smokers (36 men and 16 women; age range 43-85 years, mean age: 64 years) were selected and classified into the following four age- and gender-matched groups according to age, gender, the results of the pulmonary function test and the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guideline (10): 'Smokers without COPD (n=13)', 'Mild COPD (n=13)', 'Moderate COPD (n=13)', and 'Severe or Very Severe COPD (n=13)'. All MDCT examinations were performed with a 16-detector row CT system (Aquilion 16, Toshiba Medical Systems, Otawara, Japan) and two 64-detector row CT system (Aquilion 64, Toshiba). For a quantitative MDCT assessment, CT-based functional lung volume (CT-based FLV) and ratio of WA to total airway area (WA%) were determined by using a commercially available software (Fig. 1A and 1B). On dynamic O<sub>2</sub>-enhanced MRI, the T1-weighted images were continually collected by means of a respiratory synchronized half-Fourier acquisition centrically-reordered inversion recovery single-shot turbo spin-echo (HASTE) pulse sequence and three 1.5 T scanners (Gyrosan Achieva; Philips Healthcare, Best, The Netherlands). All O<sub>2</sub>-enhanced MR images were expressed as the percentage change between the oxygen-enhanced and baseline images and wash-in time map after oxygen-inhalation by pixel by pixel analyses (Fig. 1C and 1D), and the mean relative enhancement ratio (MRER) and mean wash-in time (MWT) for every subject was determined as the average of the relative enhancement ratio and wash-in time measured from regions of interest (ROIs) drawn over both lungs on the coronal section. To compare the efficacy of dynamic O<sub>2</sub>-enhanced MRI and quantitative MDCT for smoking-related functional loss assessment, CT-based FLV, WA%, MRER and MWT were correlated with the lifetime smoking exposure, FEV<sub>1</sub>/FVC%, FEV<sub>1</sub>% and %DL<sub>CO</sub>/V<sub>A</sub>. To evaluate the capability of the two methods for clinical stage classification, CT-based FLV, WA%, MRER and MWT were compared with those of subjects at all stages of COPD by using ANOVA followed by Tukey's HSD multiple comparison test.

**Results:** The lifetime smoking exposure had significantly fair correlations with WA% (p<0.05). FEV<sub>1</sub>/FVC had significantly moderate correlations with all CT- and MR-based indexes (p<0.05). FEV<sub>1</sub>% had significantly good correlations with WA% and MWT (p<0.05), and moderate correlation with CT-based FLV and MRER (p<0.05). %DL<sub>CO</sub>/V<sub>A</sub> had significantly good correlation with CT-based FLV and MRER (p<0.05), and moderate correlations with WA% and MWT (p<0.05). Statistical results of the lifetime smoking exposure, pulmonary functional parameters and CT-based and MR-based indexes for smoking-related COPD subjects at all stages are shown in Table 1. All CT- and MR- based indexes of "Smokers without COPD" and "Mild COPD" groups had significant difference with those of "Moderate COPD" and/or "Severe or very severe COPD" groups (p<0.05). In addition, MRER and MWT of "Smokers without COPD" group had significant difference with "Mild COPD" group (p<0.05).

**Conclusion:** Dynamic O<sub>2</sub>-enhanced MRI has potential for COPD assessment in smokers as well as quantitatively assessed thin-section MDCT.



**Figure 1.** 76-year-old male smoker in "Moderate COPD" group

A: Apical bronchus in the left upper lobe is shown as an example of quantitative measurement of six-generation bronchus. WA% was 80%. B: For assessment of CT-based FLV in the lungs, pixels showing less than -960 HU were expressed as sky blue. CT-based FLV was 0.62. C: Source image and relative enhancement map from dynamic O<sub>2</sub>-enhanced MR data demonstrate heterogeneous and markedly reduced oxygen enhancement within the lung; calculated MRER is 0.10. The relative enhancement in each pixel is expressed as a color-coded map showing pixels with 0 to 50% enhancement progressing from dark green to yellow. D: Source image and wash-in time map from dynamic O<sub>2</sub>-enhanced MR data demonstrate heterogeneous and markedly prolonged wash-in time within the lung; calculated MWT is 63 sec. The wash-in time in each pixel is expressed as a color-coded map showing pixels with 0 to 50sec enhancement progressing from dark green to yellow.

## References.

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**Table 1. Statistical results of the lifetime smoking exposure, pulmonary functional parameters and CT-based and MR-based indexes for smoking-related COPD subjects at all stages.**

	Smokers without			
	COPD	Mild COPD	Moderate COPD	Severe or very severe COPD
Cases	13	13	13	13
Age (year old)	58.1±19.6	65.6±10.1	58.9±16.6	68.6±9.1
The lifetime smoking exposure (pack year)	43.7±36.1	46.7±18.3	89.1±42.7*	89.8±36.1*
FEV <sub>1</sub> /FVC (%)	76.2±11.0	59.1±5.8*	44.9±8.4**, **	35.9±9.1*, **
FEV <sub>1</sub> % (%)	81.9±7.4	60.5±6.3*	40.1±5.8**, **	33.8±9.7*, **
%DL <sub>CO</sub> /V <sub>A</sub> (%)	85.1±11.0	64.8±8.1*	49.6±12.0**, **	38.2±8.1*, ***, **
CT-based FLV (%)	70.6±5.6	69.7±8.4	54.2±10.5*	47.3±9.5*, **
WA% (%)	63.8±7.4	66.7±6.3	73.0±7.6**, **	79.0±5.4*, **
MRER	0.22±0.05	0.14±0.05*	0.11±0.06*	0.08±0.05*, **
MWT (%)	31.5±7.1	35.4±8.7*	47.0±8.6*, **	55.4±5.3*, **

CT-based FLV: CT-based functional lung volume, WA%: Ratio of WA to total airway area, MRER: Mean relative enhancement ratio, MWT: Mean wash-in-time, r: correlation coefficient. All values are stated as mean ± standard deviation.

\*: Significant difference with "Smokers without COPD" subjects (p<0.05).

\*\* : Significant difference with "Mild COPD" subjects (p<0.05).

\*\*\*: Significant difference with "Moderate COPD" subjects (p<0.05).