Dynamic Oxygen-Enhanced MRI vs. Quantitative Thin-Section CT: Capability for Pulmonary Functional Loss Assessment and Clinical Stage Classification in Asthmatics

Yoshiharu Ohno[1], Shinichiro Seki[2], Mizuho Nishio[1], Hisanobu Koyama[2], Takeshi Yoshikawa[1], Sumiaki Matsumoto[1], Nobukazu Aoyama[3], Makoto Obara[4], Marc van Cauteren[5], Hideaki Kawamitsu[3], and Kazuro Sugimura[2]

[1]Advanced Biomedical Imaging Research Center, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, [2]Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, [3]Center for Radiology and Radiation Oncology, Kobe University Hospital, Kobe, Hyogo, Japan, [4]Philips Electronics Japan, Tokyo, Japan, [5]Philips Healthcare Asia Pacific, Tokyo, Japan

INTRODUCTION: Asthma is a chronic inflammatory disorder that predominantly involves the small and medium airways in the peripheral lungs and characterized by airflow limitation, which reverse spontaneously or in response to treat.   In the last decade, several investigators have suggested that thin-section CT and hyperpolarized noble gas MR imaging (HP-MRI) as well as oxygen-enhanced MRI (O_2-enhanced MRI) are also useful procedures for assessment of regional morphological and functional changes in asthmatics (1-3).   In addition, dynamic O_2-enhanced MRI is suggested as useful for separate assessments of regional ventilation and oxygen transfer in smokers (4).   However, there are no reports about capability of assessment of dynamic O_2-enhanced MRI for pulmonary functional loss assessment and clinical stage classification in asthmatics.   We hypothesized that dynamic O_2-enhanced MRI has potential for functional loss assessment and clinical stage classification in asthmatics as well as quantitatively assessed thin-section CT.   The purpose of the study reported here was to prospectively and directly compare the efficacy of dynamic O_2-enhanced MRI and quantitative CT for functional loss assessment and clinical stage classification in asthmatics.

MATERIALS AND METHODS: A total 30 consecutive asthmatics (17 men and 13 women; age rang 27-78 years) underwent dynamic O_2-enhanced MRI, thin-section MDCT and pulmonary function test (FEV_1% and FEV_1/FVC%).   All asthmatics were classified into four stages ('Mild Intermittent [n=7]', 'Mild Persistent [n=5]', 'Moderate Persistent [n=12]' and 'Severe Persistent [n=6]') according to the Global Initiative for Asthma guideline.   All dynamic O_2-enhanced MRI were obtained by means of respiratory synchronized half-Fourier acquisition centrically-reordered inversion recovery single-shot turbo spin-echo (HASTE) pulse sequence at three 1.5 T scanners.   From signal intensity-time course curves, relative enhancement ratio and wash-in time maps in each subject were generated by pixel by pixel analyses.   Then, ROIs were placed over the lung, and averaged to determine mean relative enhancement ratio (MRER) and mean wash-in time (MWIT) in each subject.   On quantitative CT in each subject, ratios between wall area and total area of bronchus in right apical and anterior basal bronchi were averaged as WA%.   In addition, mean lung density (MLD) of the entire lung was also measured.   To compare the capability for pulmonary functional loss assessment between dynamic O_2-enhanced MRI and quantitative CT, all radiological indexes were correlated with FEV_1% and FEV_1/FVC%.   To determine the capability of two modalities for clinical stage classification, each index was statistically compared among three clinical stages by means of Fischer's PLSD test.   A p value less than 0.05 was considered as significant on each statistical analysis.

RESULTS: Representative case is shown in Figure 1.   On correlation of pulmonary function test results and each index, FEV_1/FVC had significant and moderate correlations with MRER (r=0.70, pp<0.0001), MWIT (r=-0.75, p<0.0001), MLD (r=0.45, p=0.01) and WA% (r=-0.56, p=0.001).   In addition, %FEV_1 also had significant and moderate correlations with MRER (r=0.74, p<0.0001), MWIT (r=-0.80, p<0.0001), MLD (r=0.42, p=0.02) and WA% (r=-0.62, p=0.0003).   Correlation coefficients of both dynamic O_2-enhanced MR indexes were better than that of both quantitatively assessed thin-section CT indexes.   Detailed characteristics of the four clinical stage groups and the results of the statistical comparison of all indexes for clinical stage classification are shown in Table 1.   Although MWIT had significant difference among all clinical stages in asthmatics (p<0.05), there were significant differences of MRER among all clinical stages (p<0.05) except that between 'Mild Intermittent' and 'Mild Persistent' groups.   In addition, WA% of 'Severe Persistent' group had significant difference with that of others (p<0.05).

CONCLUSION: Dynamic O_2-enhanced MRI was found to be effective for pulmonary functional loss assessment and clinical stage classification of asthmatics as well as quantitative thin-section CT.   In addition, dynamic O_2-enhanced MR indexes had better correlation with pulmonary function test results, and had better potential to demonstrate significant differences among clinical stages in asthmatics than quantitatively assessed thin-section CT.

| Fig. 1A | Fig. 1B | Fig. 1C |
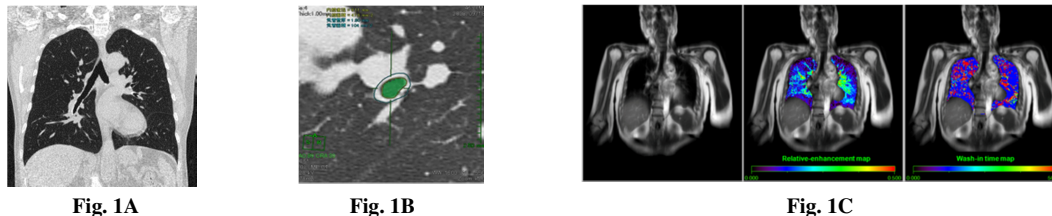
Figure 1. 55-year old female in 'Moderate Persistent' asthma patient
    A: Thin-section MPR image demonstrate no emphysema, and MLD is assessed as -890 HU.   B: Quantitatively assessed WA % is determined as 58.6%.   C (L to R: Source image, relative-enhancement ratio map and wash-in time map): MRER is determined as 0.19, and MWIT is assessed as 28.0 sec.

Table 2. Characteristics and statistical results of quantitatively assessed CT and O_2-enhanced MR parameters for all groups.

Indexes	Asthma Classification			
	Mild Intermittent (n=7)	Mild Persistent (n=5)	Moderate Persistent (n=12)	Severe Persistent (n=6)
Age	56.0±14.6	58.2±10.9	55.8±12.6	57.2±13.2
FEV_1/FVC (%)	85.3±8.6	77.3±5.5	6.311.6*, **	50.8±6.9*, **, ***
%FEV_1 (%)	93.7±7.3	83.2±2.2*	71.6±6.5*, **	48.5±7.2*, **, ***
MLD (HU)	-860.0±32.7	-880±31.0	-883.9±18.6	-884.2±18.6
WA% (%)	60.0±4.2	60.2±4.4	63.9±4.1	70.0±6.3*, **, ***
MRER	0.25±0.06	0.22±0.04	0.20±0.04*, **	0.10±0.03*, **, ***
MWIT (sec)	16.1±3.8	22.4±2.8*	26.8±3.3*, **	31.1±5.1*, **, ***

All values represent mean ± standard deviation.

MLD : Mean lung density, WA% : Ratio between wall area and total airway area, MRER: Mean relative enhancement ratio, MWIT: Mean wash-in time
*: Significant difference with 'Mild Intermittent' group (p<0.05).   **: Significant difference with 'Mild Persistent' group (p<0.05).   ***: Significant difference with 'Moderate Persistent' group (p<0.05).

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