Lung MR Imaging with Ultra-Short TE at 3.0T system: Capability for Pulmonary Functional Loss due to COPD

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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 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. Currently, CT is most widely used for radiological disease severity assessment in COPD, and in clinical and academic practice, several commercially available or proprietary software and visual scoring systems have been adapted for CT-based assessment of COPD. On the other hand, hyperpolarized noble gas MR imaging and oxygen-enhanced MR imaging on a 1.5 T MR system have been suggested as a new technique for assessment of COPD in the last decades. Currently, the clinical use of 3.0T systems is expanding from neuro MR imaging into body imaging (3, 4). In addition, several investigators have tried to determine the utility of regional T2* measurement in the lung in animal and human studies. We hypothesized that direct T2* measurement in the lung has a potential role to play as a new method for pulmonary functional loss assessment at 3.0 T in routine clinical practice. The purpose of this study is to determine the capability of Lung MR imaging with ultra-short TE (UTE MRI) at 3T for measurement of regional T2* in the lung and pulmonary functional assessment in normal and COPD subjects.

Materials and Methods: Five normal volunteers (3 men and 2 women; mean age 67 years) and 15 COPD patients (10 men and 5 women; mean age 69 years) underwent UTE MRI for quantitative T2* measurement at 3T MRI (Gyroscan Achieva 3T, Best, the Netherlands) and pulmonary functional measurements (FEV_1/FVC%, FEV_1% and $\%DL_{CO}/V_A$). All UTE MRI were obtained by using a 3D rephrased radial sampling sequence with UTEs (TR 10ms/ TE 0.2, 0.7, 1.2, 1.7, 2.2, 2.7, 3.2, 3.7, 4.2, 4.7 ms/ Flip angle 8 degree/ voxel size 3.52×3.52×3.52 mm/ 64×64 matrix, 128×128 reconstruction matrix, 1 NEX, 70 slices). The multi-echo UTE MR data were analyzed using the manufacture-provided software (Philips Healthcare). The signal intensity (SI) vs. time course curve in each pixel was fitted by using the formula: $S(t) = S(0) \exp(-t/T2^*)$, where t is time after excitation. S(0) and S(t) are SI at TE of 0 or t msec, respectively. Then, regional T2* maps were determined in each subject by pixel-by-pixel analysis (Figure 1). To determine the capability to assess regional differences of T2* on iso-gravitational and gravitational directions, regional T2* values at each lung field in normal subjects were statistically compared to each other by using Turkey's HSD test. To compare mean T2* values between normal and COPD subjects, mean T2* values were statistically compared with Student's t-test. To assess the capability for pulmonary functional loss assessment, the mean T2* value was correlated with FEV_1/FVC%, FEV_1% and $\%DL_{CO}/V_A$. A p value less than 0.05 was considered significant for all statistical analyses.

Results: On comparison of regional differences of T2* values on gravitational direction, mean T2* value at dorsal potion (0.54±0.14 ms, mean±standard deviation) was significantly longer than that at ventral (0.36±0.04 ms, $p<0.05$) and central (0.41±0.06 ms, $p<0.05$). When comparing mean T2* values in the iso-gravitational directions, there were no significant differences of mean T2* value among all lung fields. Results of comparison of mean T2* values between normal and COPD subjects is shown in Figure 2. The mean T2* value of COPD subjects (0.37±0.04 ms) was significantly shorter than that of normal subjects (0.55±0.03 ms, $p<0.05$). Regarding correlations between mean T2* value and pulmonary functional parameters, mean T2* value had significant and positive correlations with FEV_1/FVC% ($r=0.87$, $p<0.0001$), FEV_1% ($r=0.88$, $p<0.0001$) and $\%DL_{CO}/V_A$ ($r=0.93$, $p<0.0001$).

Conclusion: UTE MRI on a 3T MR system was useful for pulmonary functional loss assessment in COPD subjects. The UTE MRI at 3T could also measure regionally varying T2* values in the lung, and demonstrate significant difference between normal and COPD subjects. In addition, regional T2* measurement of the pulmonary parenchyma with ultra-short TE has the potential to be a new diagnostic method for pulmonary functional assessment in COPD subjects.

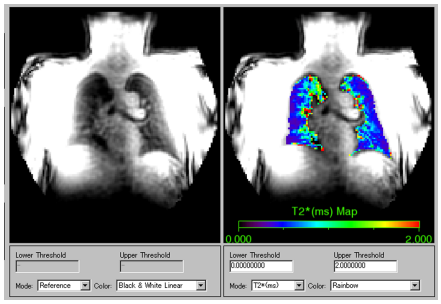

Figure 1. Examples of source image and calculated regional T2* map
(L to R: Source image to T2* map) Calculated regional T2* map demonstrates regional difference of T2* value within the lung.

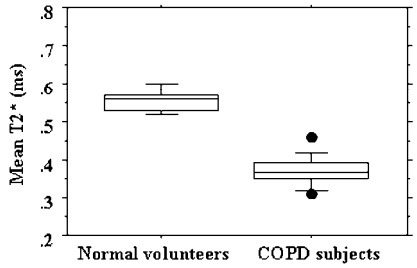

Figure 2

Figure 2. Differences between normal and COPD subjects.
There were significant difference of mean T2* value between normal and COPD subjects ($p<0.05$).

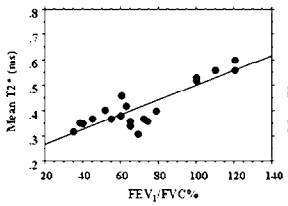

Figure 3A

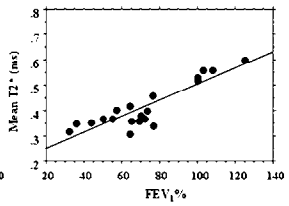

Figure 3B

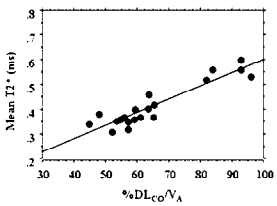

Figure 3C

Figure 3. Correlations between pulmonary functional parameters and mean T2* value in all subjects.
A: FEV_1/FVC% had significant and positive correlation with mean T2* value ($r=0.87$, $p<0.0001$).
B: FEV_1% had significant and positive correlation with mean T2* value ($r=0.88$, $p<0.0001$). C: $\%DL_{CO}/V_A$ had significant and positive correlation with $\%DL_{CO}/V_A$ ($r=0.93$, $p<0.0001$).

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