Pulmonary 3T MR Imaging with Ultra-Short TEs: Influence of Ultra-Short Echo Time on Pulmonary Functional and Clinical Stage Assessments of Smokers

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Introduction: In 2010, pulmonary MR imaging using ultra-short echo times (TEs) was introduced as a new tool in conjunction with the 3T MR system for the direct and quantitative measurement of T2* values in the lung parenchyma (1-3). With this technique, parenchymal structures can be quantitatively assessed according to magnetic field inhomogeneity. In addition, measured T2* values correlate well with CT-based functional lung volume of smokers, so that pulmonary MR imaging with ultra-short TEs (UTE-MRI) may perform a complementary role to CT or MDCT (3). One of the technical concerns in use of the technique for various 3T systems is whether the accuracy of this method may change due to selection of TEs in T2* measurement in lung parenchyma since different 3T system has different flexibility to select a train of TEs. ɫ If this is the case, use of appropriate ultra-short TE intervals for UTE-MRI is therefore essential for application of this method in clinical practice. In this study, we tested our hypothesis that T2* measured in a shorter UTE interval provides higher sensitivity for such assessment of pulmonary dysfunction and classification of COPD on UTE-MRI in smokers. We measured the T2* in the lung parenchyma by three different sets of TEs and compared the abilities of each measured T2* with quantitatively assessed thin-section CT for assessment of pulmonary functional loss and clinical stage classification of smokers.

Materials and Methods: Sixty consecutive smokers with and without COPD (43 men and 17 women; mean age 70 years) underwent thin-section MDCT, pulmonary UTE-MR imaging,,and pulmonary functional measurements. The subjects were classified into four groups according to the results of the pulmonary function test and the GOLD guidelines: 'smokers without COPD (n=12)', 'with mild COPD (n=16)', 'with moderate COPD (n=24)', and 'with severe or very severe COPD (n=8)'. All pulmonary UTE-MR images were obtained in a 3.0 T MR scanner by using three rephased multiple gradient echo 3D radial "kooshball" sampling sequences using a 6-channel phased-array coil. In each subject, T2* measurement was repeated three times in the following protocols: TR 10ms, TE 0.2, 0.7, 1.2, 1.7, 2.2, 2.7, 3.2, 3.7, 4.2, and 4.7 ms for the first scan (UTE-MRI A); TR 20ms, TE 0.2, 1.2, 2.2, 3.2, 4.2, 5.2, 6.2, 7.2, 8.2, and 9.2 ms for the second scan (UTE-MRI B); TR 30ms, TE 0.2, 1.7, 3.2, 4.7, 6.2, 7.7, 9.2, 10.7, 12.2, and 13.7 ms for the third scan (UTE-MRI C). Other parameters were constant at each protocol. The multi-echo UTE MR data were analyzed using the manufacture-provided software, and mean T2* value in the lung was calculated in each subject (3). According to the past literature (3), disease severity of COPD in each patient was assessed as CT-based functional lung volume (FLV). To determine the influence of ultra-short TE intervals on T2* measurement, mean T2* values measured with three protocols were statistically compared by means of Tukey's honest significance tests. To determine the correlations of CT- and MR-based indexes with lifetime smoking exposure and results of pulmonary functional tests, CT-based FLV and mean T2* values were correlated with lifetime smoking exposure, $FEV_1/FVC\%$, $\%FEV_1$ and $\%DL_{CO}/V_A$. To determine differences for each index among smokers of all groups, both indexes were compared by means of Tukey's honest significance test.

Results: Representative case is shown in Figure 1 and 2. Comparison of the measured mean T2* values showed that there were significant differences among all protocools (p<0.05). Correlations among all CT- and MR-based indexes, lifetime smoking exposure, $FEV_1/FVC\%$, $FEV_1\%$ and $\%DL_{CO}/V_A$ show that lifetime smoking exposure significantly and negatively correlated with the CT-based FLV and mean T2* values as assessed by UTE-MRI A and B (-0.62≤r≤-0.45; p≤0.0003). $FEV_1/FVC\%$, $\%FEV_1$ and $\%DL_{CO}/V_A$ showed significant and positive correlation with the CT-based FLV and mean T2* value assessed with each UTE sequence (0.37≤r≤0.79; p≤0.0035). All correlation coefficients for UTE-MRI A were higher than those for the CT-based FLV, as were those for UTE-MRI B except for $\%DL_{CO}$. However, all correlation coefficients for UTE-MRI C were lower than those for CT-based FLV. Statistical results for the CT- and MR-based indexes for smokers without and with COPD at all stages are listed in Table 1. The CT-based FLV and mean T2* values assessed by all UTE-MRIs except UTE-MRI C showed significant differences among all groups except between smokers without COPD and those with mild COPD (p<0.05). On the other hand, the mean T2* value assessed by UTE-MRI C for smokers without COPD showed a significant difference with that smokers with moderate COPD and with severe or very severe COPD (p<0.05).

Conclusion: The UTE interval for pulmonary MR imaging using UTEs is an important parameter for pulmonary functional loss assessment and clinical stage classification of smokers, and shorter UTE intervals should be used for better results in this setting.
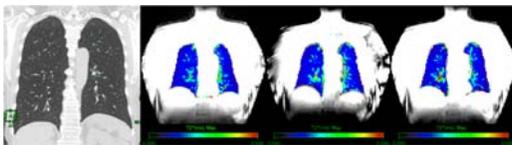

Figure 1A **Figure 1B**

Figure 1. 56-year-old male in 'smokers with mild COPD' group.
A: Quantitatively assessed thin-section CT shows low attenuation areas equal to or less than -960 HU as sky blue spots in the lungs. CT-based FLV was 97.5 %. B: (L to R: UTE-MRI A, UTE-MRI B and UTE-MRI C) Each UTE-MRI shows relatively homogeneous T2* values for the lungs. Mean T2* values for UTE-MRI A, B and C were 1.0 ms, 1.2 ms and 1.4ms, respectively.
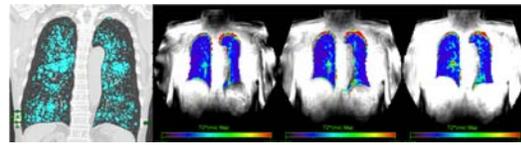

Figure 2A **Figure 2B**

Figure 3. 69-year-old male in 'smokers with severe or very severe COPD' group.
A: Quantitatively assessed thin-section CT shows low attenuation areas equal to or less than -960 HU as sky blue spots in the lungs. CT-based FLV was 48.9 %. C: (L to R: UTE-MRI A, UTE-MRI B and UTE-MRI C). Each UTE-MRI demonstrates relatively homogeneous T2* values for the lungs. Mean T2* values for UTE-MRI A, B and C were 0.64 ms, 0.67 ms and 0.72ms, respectively.

Table 1. Statistical findings for CT-based functional volume and mean T2* value obtained with each sequence for smokers without COPD and with all stages of COPD

	Smokers without COPD	with mild COPD	with moderate COPD	with severe or very severe COPD
CT-based functional lung volume (mean±SD <%>)	78.3±7.3	76.1±7.1	63.7±9.2*, **	53.8±9.9*, **, ***
T2* measurement obtained with sequence A (mean±SD <msec>)	0.87±0.12	0.79±0.07	0.63±0.08*, **	0.48±0.11*, **, ***
T2* measurement obtained with sequence B (mean±SD <msec>)	0.90±0.07	0.84±0.07	0.75±0.07*, **	0.63±0.14*, **, ***
T2* measurement obtained with sequence C (mean±SD <msec>)	1.02±0.18	0.86±0.1	0.83±0.16 *	0.74±0.12*

SD: Standard deviation; T2*: T2-star; *: Significant difference with smokers without COPD (p<0.05); **: Significant difference with smokers with mild COPD (p<0.05); ***: Significant difference with smokers with moderate COPD (p<0.05)

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