Comparison of Lung T2* Measurements at 1.5T and 3.0T with Ultrashort Echo Time (UTE) Sequence

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Introduction: The short T2* of lung is mainly caused by the magnetic susceptibility difference between lung tissue and airway. Accurate assessments of lung T2* may be important as it has the potential to detect structural and functional changes caused by lung diseases such as emphysema, chronic bronchitis and fibrosis. For example, emphysema irreversibly destroys the tissues of the alveolar wall and this structure changes will directly modify the local magnetic susceptibility. Takahashi et.al. reported that T2* decreases in an emphysematous mouse model[1]. In terms of functional changes, chronic bronchitis impairs the lung oxygen absorption capability and thus affects the local oxygen concentration, which will be consequently reflected in the local magnetic susceptibility changes. Pracht et.al. demonstrated that mean T2* difference between room air and 100% O2 is about 10% in normal lungs at 1.5T [2]. T2* measurement of the lung is challenging mainly due to relatively low proton density and susceptibility-induced fast signal decay. While T2* measurements of the lungs have been carried out in both animals and humans at 1.5T [3,4], studies on human lung at 3T have not yet been reported, and it is yet unclear whether the higher field strength will offer any advantage. In this work, we present a comparison of lung T2* measurements in normal human subjects at 1.5T and 3.0T using an ultrashort echo time (UTE) pulse sequence.

Methods: A 2D UTE sequence was implemented on Siemens Sonata 1.5T and Trio 3.0T MRI systems. The UTE sequence combines half-sinc RF excitation, variable rate excitation (VERSE), half-echo projection acquisition and ramp sampling techniques [5]. Minimum echo times of 50us and 30us were achieved at 1.5T and 3.0T respectively.

The lungs of two healthy male volunteers were imaged on both scanners using the transmit/receive body coil. Axial images were acquired with the following parameters: FOV=300mm; Slice thickness=20mm; TR=10ms; Flip angle=7 degrees; Readout points=256. The readout bandwidth was 651Hz/Pixel at 1.5T and 1302 Hz/Pixel at 3.0T. Data were acquired during free breathing, and a golden angle view order was used in which an angle of 137.51° advanced successive view angles [6]. A series of nine TE values were acquired: [0.05, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 4.0ms] for 1.5T and [0.03, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 2.0ms] at 3.0T. Ten thousand angular views were acquired at each TE for a scan time of 3.4 minutes at each echo time.

During data processing, the left and right lungs were first manually segmented. The images were then thresholded based on the first echo image to exclude the large blood vessels, followed by a mono-exponential fitting. In the fitting for 1.5T, the first point was excluded due to signal irregularities (lower than expected signal) possibly due to insufficient receiver dead time.

		Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	SNR	
								Left lung	Right lung
Subject1	1.5T	**2.38**	**1.75**	**2.42**	**2.32**	**2.11**	**2.90**	9.7	10.4
	3.0T	**0.65**	**0.56**	**0.94**	**0.75**	**0.52**	**1.12**	13.8	10.3
Subject2	1.5T	**2.23**	**1.74**	**2.07**	**3.05**	**1.68**	**2.23**	10.0	10.5
	3.0T	**0.70**	**0.62**	**0.62**	**0.75**	**0.69**	**0.71**	12.7	11.3

Table.1 Measured lung T2* values (unit ms) of the normal subjects at 1.5T and 3.0T. The corresponding regions are labeled in Fig.1(d). The signal-to-noise ratio (SNR) corresponds to the first TE in each measurement.

Results and Discussion: Table 1 shows the T2* values in the six regions (anterior, middle and posterior regions of each lung) of the two subjects at 1.5T and 3.0T. The overall average T2* was 2.24 (±0.43) ms and 0.72 (±0.17) ms at 1.5T and 3T, respectively, a ratio somewhat larger than the ratio of the two field strengths. Figure 1 (a)-(c) shows the lung images at TE= 0.03ms, 0.3ms and 0.7ms at 3T. Figure 1 (d) labels the six regions used for T2* calculations in Table 1. Figure 2 shows a plot of the measured points and the fitted curves for one of the regions. In Table 1, it can be observed that the middle regions (2 and 5) of lung have somewhat lower T2* value than the anterior and posterior regions. This observation is in agreement with previous findings [4]. The table also shows that the signal-to-noise (SNR) ratios are similar at the two field strengths. This is in part due to the higher acquisition bandwidth, and presumably longer T1, at the higher field strength.

In the UTE sequence, two RF excitations with opposite slice selective gradient polarity are combined to form the desired slice profile excitation, while eliminating out-of-slice contributions. Therefore it is important to monitor the combined slice profile to ensure accuracy. For this purpose, the slice profile was imaged by rotating one of the readout gradients to the slice direction. As shown in Fig. 3, the image acquired with the body coil demonstrates a cleaner slice profile than the local cardiac array coil. For this reason, the body coil was used for this study.

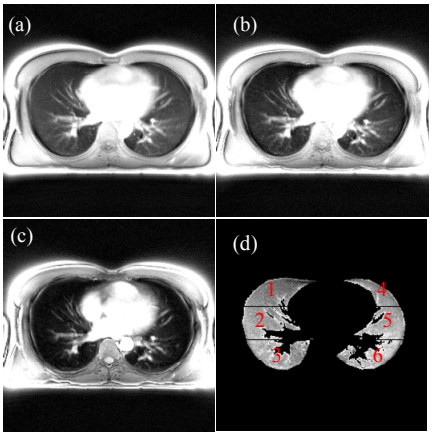

Figure.1 Lung images of subject 2 at 3.0T. (a)-(c) are images acquired with UTE sequence at TE = 0.03 0.3 0.7ms, respectively. (d) shows the six regions used for T2* calculations.

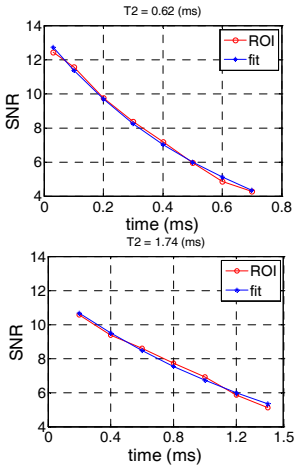

Figure.2 Signal decay vs. fitting curves for lung region 2 of subject 2 at (a) 3.0T and (b) 1.5T

Conclusion: In this work, T2* of the lungs in normal human subjects were compared at 1.5T and 3.0T utilizing an ultrashort echo time (UTE) sequence. The average T2* 0.72 (±0.17) ms at 3.0T is considerably shorter than 2.2 (±0.43) ms at 1.5T. Although 3T may offer higher sensitivity to changes in the lung due to disease, the significantly increased T2* decay and resultant signal loss may potentially negate any advantages of the higher field strength.

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References: [1] Takahashi M et. al., ISMRM2009, 00011. [2] Pracht E et. al., Magn Reson Med, 53:1193-1196 (2005). [3] Bergin CJ et. al., Radiology, 179:777-781 (1991). [4] Hatabu H et. al., Eur J Radiol, 29:245–252 (1999). [5] Gewalt SL et al., Magn Reson Med, 29(1):99-106 (1993). [6] Lin W, et. al., Magn Reson Med, 60:1135-1146 (2008).

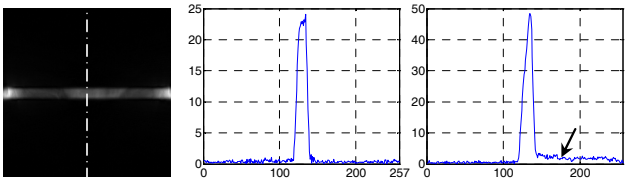

Figure.3 slice profile of UTE2d excitation for subject 1 at TE=0.2ms at 1.5T. (a) slice profile imaged with body coil (b) signal profile corresponding to the dotted line in (a). (c) signal profile in the image (not shown here) acquired with chest array coil. The arrow indicates the outer-slice signal caused by the mismatch of the two RF excitations in UTE imaging.