Pulmonary T2* dependence on the lung volume: preliminary results

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Introduction

During ventilation, the alveolar walls expand and contract. It has been shown on excised lungs that this process is accompanied with alveolar shape changes – at lower lung volumes the alveoli have more of a spherical shape, while at higher lung volumes, close to TLC, the walls are fully stretched and resemble more a polyhedron with smoothed corners [1] than a sphere. Such shape changes can affect the field homogeneity in the tissue caused by a susceptibility difference between air and tissue. We therefore hypothesized that lung volume will affect the T_2^* of the lung tissue and measured T_2^* at three different lung volumes: (1) after full exhalation at residual lung volume (RV); (2) after end-expiration at functional residual capacity (FRC); and (3) after full inhalation at total lung capacity (TLC).

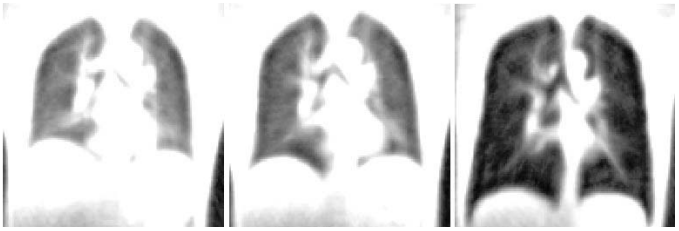

Figure 1. Proton images of a lung slice at 3 lung volumes: (a) RV, (b) FRC and (c) TLC.

Materials and Methods

Data was acquired on a 1.5T Siemens Avanto scanner (Fig.1). The protocol was approved by our local IRB and written consent was obtained from subjects prior to their participation. For each scan, subjects performed a 30s breath-hold in the supine position. 3D Ultra-short echo time radial acquisition sequence (UTE) was used with 3000 radial views, 192 points in each, TR=12.4 ms, BW = 130 Hz/pixel, flip angle = 7°, FOV = 50cm and six different TE values: [0.05, 0.1, 0.2, 0.5, 1, 2] ms (Fig.2). Reconstructed images were read into Matlab, lung regions segmented for each lung volume and then the signal from the runs with different TE's were fit to a mono-exponential function on a pixel-by-pixel basis. We also measured T_2^* on a Siemens 3T Tim Trio at a single lung volume (near RV) during a breath-hold after breathing air and then after breathing 100% oxygen.

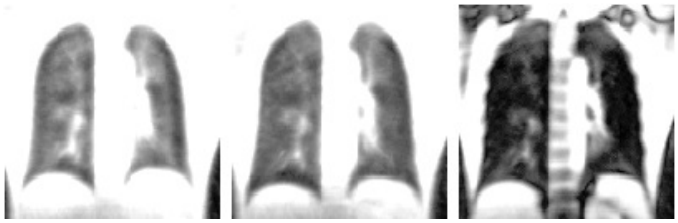

Figure 2. Lung images at three TE values: (a) 0.1, (b) 0.5 and (c) 2ms.

Results

Sample data with a fit are plotted in Fig.3a. It is evident from the plot that the signal at two shortest TE's is suppressed, similar to what Yu *et. al* reported last year [2]. Some of this might be due to the coil recovery time. On the other hand, T_2^* for heterogeneous media has been shown to deviate from the mono-exponential decay [3]. T_2^* values changed depending on how many points were used in the fit. If all 6 TE measurements were used, T_2^*=3.0ms, when the 50us measurement was neglected, T_2^*=2.7ms, and if only TE≥100us data were used (last 4 points in Fig.3b), T_2^*=2.4ms. Generally, the mean values at higher volumes were slightly higher than the values at lower volumes, however the distributions are wider than their separation (Fig.3b). The measured values for T_2^* are (using last 4 points): @RV – 2.4±0.12ms; @FRC – 2.6±0.12ms; and @TLC – 2.7±0.1ms.

We measured T_2^* at 3T (Fig.3c): after breathing air T_2^*=1.2±0.2ms; and after breathing 100% O_2 for 2min, T_2^*=1.1±0.2ms. The change due to paramagnetic O_2 is 10.7%.

Discussion and Conclusions

T_2^* relaxation time in the lungs was measured for 3 lung volumes: near RV, FRC and TLC at 1.5T magnetic field strength. The signal behavior with TE (Fig.3a) suggests that T_2^* does not necessarily follow mono-exponential behavior and more sophisticated model [3] needs to be used for proper relaxation time estimation.

Under the assumption of mono-exponential behavior, our measured T_2^* at both 1.5T (2.4ms) and 3T (1.2ms) are longer compared to those previously reported by Yu *et al.* (2.2ms @ 1.5T and 0.72ms @3T) [2] and by Pracht *et. al.* (1.8ms @ 1.5T, air) [4]. This difference may be because our measurements were done during a breath-hold compared to free breathing for the literature values. Mean values suggest a small increase in T_2^* with lung volume (Fig.3b). Regarding our measurements at 3T, we observed a 10% change in T_2^* due to breathing 100% O_2 vs. air. This is in agreement with that previously reported at 1.5T [4].

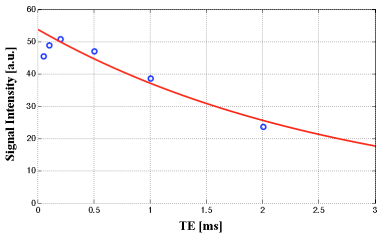

Figure 3a. Typical fit of 1.5T data. Such fits were performed in each slice on a pixel-by-pixel basis for each lung volume.

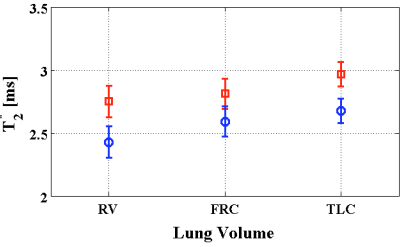

Figure 3b. T_2^* versus lung volume at 1.5T. Higher values for T_2^* were obtained for higher lung volumes (red corresponds to fits using 5 data point, blue – 4 data points).

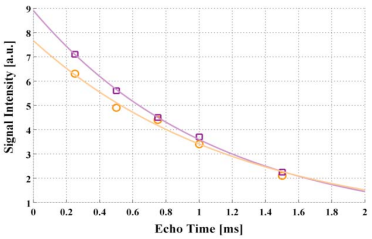

Figure 3c. Typical fits to 3T data from breath-hold scans after breathing air (orange circles) or breathing O_2 for 2 min (purple squares).

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