Ventilation imaging using DC-navigated oxygen-enhanced 2D-UTE

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Introduction

T2* relaxation times in lung tissue are extremely short due to B0 inhomogeneities caused by the boundaries between different magnetic susceptibilities of air in the alveoli and the surrounding blood vessels. Thus, T2* in the lungs varies with structural changes and between expiration and inspiration. In addition, due to the paramagnetic nature of molecular oxygen (O2), the oxygen concentration in the breathing gas has an effect on lung T2* (1). Breathing 100% O2 has been found to reduce T2* (2), depending on lung ventilation. However, to observe the wash-in of O2, T2* changes due to the breathing state and the O2 in the breathing gas have to be separated. To this end, a 2D Ultra Short TE (UTE) sequence and DC-signal navigation (3,4,5) were employed.

Method

All measurements were performed on a 1.5T clinical scanner. T2* was measured using a 2D UTE multi-gradient echo sequence (6). A half-sinc pulse excitation and center-out radial readout were used to accomplish a minimum echo time (TE) of 70μs. After each RF excitation, 4 echoes where acquired at TE=70μs, 1.4ms, 2.8ms and 4.2ms with a TR of 6.4ms. Radial trajectories were distributed quasi-randomly over time using a golden angle increment of 111.5°. About 49000 radial trajectories were acquired continuously over 10min during free breathing, first switching breathing gas from room air (RA) to 100% O2 after 1 minute and back after 5 minutes. From this data quantitative T2* maps were calculated at an interval of 0.33s from 144 neighbouring projections each to allow tracking T2* changes on a pixel by pixel basis over the course of the experiment. In Fig.1a the median lung T2* time-curve is displayed showing both the reduction in T2* during the O2-phase and additional oscillations due to respiratory motion. A second set of T2* maps was calculated by navigating with the DC-signal, i.e. the signal in k-space centre (6). By choosing trajectories accordingly, T2* maps were calculated for 10 different breathing states between full expiration and inspiration, both for the entire experiment and O2 and room-air- phases separately. Since the DC-signal contains the breathing state for each time-point during the experiment, the median T2* values from the navigated maps can be used to produce an estimated T2* time curve (shown in Fig.1b) containing only the effects caused by breathing, independent of breathing gas. Finally, this curve was subtracted from the measured time-curve (Fig.1a), resulting in a corrected curve (Fig.1c) representing only T2* changes due to the breathing gas.

Results

The uncorrected T2* time-curve shown in Fig.1b shows both oscillations due to respiration and the effect of changing O2 concentration. After correction using DC-navigation, the effects of T2* changes due to breathing are greatly reduced even in the case of irregular breathing. This enables calculating the O2 wash-in and -out times by exponential fits (Fig.1d) resulting in wash-in times of 18.4s (after t1) and 31.1s (t2), at a relative change of 8.8%. Since the navigated maps were reconstructed for identical breathing states, they could be subtracted to yield difference maps, shown in Fig.2.

Conclusions

Navigated T2* maps can be used to calculate difference maps without the need for image registration in spite of T2*-variations over the lung volume. Furthermore, separating the effects of breathing and O2 concentration greatly increases the visibility of oxygen-wash-in and wash-out in T2*, allowing for a fit of wash-in-times. These were found to be on the same order as those found in T1 under oxygen wash-in and wash-out (7).

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References