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

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Introduction

T_2* relaxation times in lung tissue are extremely short due to B_0 inhomogeneities caused by the boundaries between different magnetic susceptibilities of air in the alveoli and the surrounding blood vessels. Thus, T_2* in the lungs varies with structural changes and between expiration and inspiration. In addition, due to the paramagnetic nature of molecular oxygen (O_2), the oxygen concentration in the breathing gas has also an effect on lung T_2*: Breathing 100% O_2 has been found to reduce T_2*[1], depending on lung ventilation. However, to observe the wash-in of O_2, T_2* changes due to the breathing state and the O_2 in the breathing gas have to be separated. To this end, a 2D Ultra Short TE (UTE) sequence and DC-signal navigation[2,3] were employed.

Method

All measurements were performed on a 1.5T clinical scanner. T_2* was measured using a 2D UTE multi-gradient echo sequence[4]: 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[5] 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% O_2 after 1 minute and back after 5 minutes. From this data quantitative T_2* maps were calculated at an interval of 0.33s from 144 neighbouring projections each to allow tracking T_2* changes on a pixel by pixel basis over the course of the experiment. In Fig.1a the median lung T_2* time-curve is displayed showing both the reduction in T_2* during the O_2-phase and additional oscillations due to respiratory motion. A second set of T_2* maps was calculated by navigating with the DC-signal, i.e. the signal in k-space centre[6]: By choosing trajectories accordingly, T_2* maps were calculated for 10 different breathing states between full expiration and inspiration, both for the entire experiment and O_2 and room-air-phases separately. Since the DC-signal contains the breathing state for each time-point during the experiment, the median T_2* values from the navigated maps can be used to produce an estimated T_2* 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 T_2* changes due to the breathing gas.

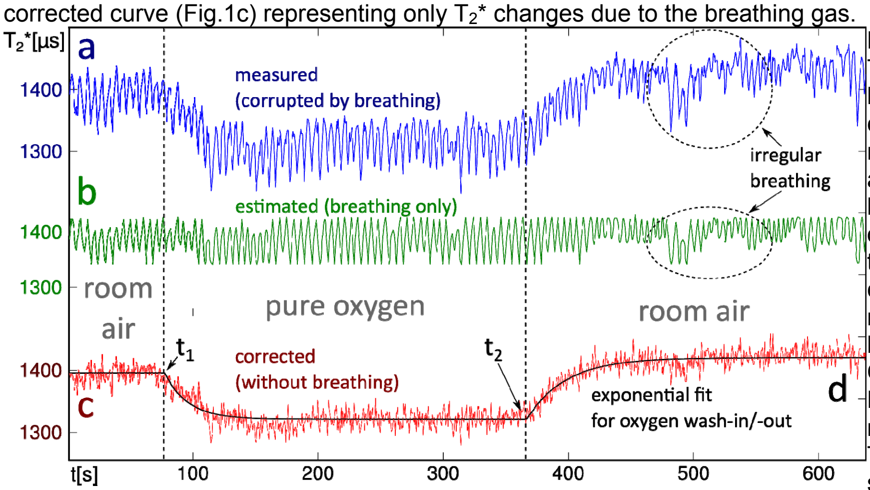

Figure 1: Measured, estimated and corrected T_2-curves of a healthy volunteer.*

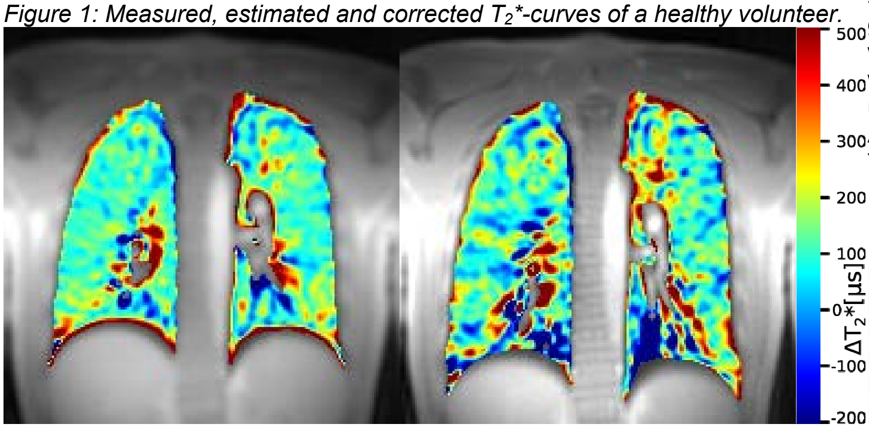

Figure 2: Corresponding T_2 difference-maps in expiration and inspiration.*

Results

The uncorrected T_2* time-curve shown in Fig.1b shows both oscillations due to respiration and the effect of changing O_2 concentration. After correction using DC-navigation, the effects of T_2* changes due to breathing are greatly reduced even in the case of irregular breathing. This enables calculating the O_2 wash-in and -out times by exponential fits (Fig.1d) resulting in wash-in times of 18.4s (after t_1) and 31.1s (t_2), 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 T_2* maps can be used to calculate difference maps without the need for image registration in spite of T_2*-variations over the lung volume. Furthermore, separating the effects of breathing and O_2 concentration greatly increases the visibility of oxygen-wash-in and wash-out in T_2*, allowing for a fit of wash-in-times. These were found to be on the same order as those found in T_1 under oxygen wash-in and wash-out[7].

Acknowledgements

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References

[1]Pracht,ED. et al.: MRM,1193-1196 (2005)
[2]Hatabu,H. et al.: EJR,245-252 (1999)
[3]Yu,J. et al.:MRM (2011)
[4]Pauly,J. et al.:JMR,43-56 (1989)
[5]Winkelmann, S. et al.: IEEE TMI 26, 68-76 (2007)
[6]Spraggins, T.A.: MRI 8,675-681 (1990)
[7]Arnold, J.F.D. et al.: MAGMA 16,246-253 (2004)