T_2 Mapping of the Lung in breath-hold Time using Radial TSE Acquisition and Nonlinear Inversion Reconstruction

Michael Völker[1], Shermiyah Baguisa[2], Martin Blaimer[1], Felix Breuer[1], and Peter Jakob[1,3]

[1]Magnetic Resonance Bavaria, Würzburg, Germany, [2]Department of Physics, Ryerson University, Toronto, Canada, [3]Department of Experimental Physics 5, University of Würzburg, Germany

Introduction:

In ^{1}H lung MRI, quantification of tissue parameters is complex due to signal properties and measurement conditions. This makes quantitative MRI challenging to implement into clinical routine. The inherently low proton density of the lung parenchyma and rapid signal decay, with T_2^* relaxation time roughly 1-2 ms at 1.5 T [1], leads to an extraordinarily weak signal. Furthermore, respiratory motion, heartbeat and pulsatile blood flow limit feasible acquisition techniques. Reducing the acquisition time to a short breath-hold period allows for an easy setup without additional triggering equipment, or error-prone image registration techniques in post-processing. In this work, the possibility of fast T_2 quantification is shown using undersampled data from an efficient radial Turbo Spin-Echo sequence [2], and processed by a nonlinear inversion reconstruction approach [3,4]. In one expiration period of 13 s, spatially resolved T_2 maps of 6 slices were obtained.

Methods:

A multi-slice Spin-Echo train sequence was implemented on a 1.5 T clinical MR scanner that allowed for radial Turbo Spin-Echo sampling (rTSE) [2] as well as Cartesian Multi Spin-Echo (MSE) acquisition. For rTSE, a modified ordering scheme based on the Golden Ratio was used [5], yielding a nearly uniform distribution of projections with identical TE in k-space [6]. Spin-density (M_0) and T_2 maps were iteratively fitted to undersampled rTSE data using a nonlinear inversion approach described in [3,4]. To accelerate all required Fourier Transform computations in the iteration loop, Cartesian k-spaces were created by gridding the radial data using GROG [7]. The reconstruction method was validated on a phantom consisting of containers with doped water. As a Gold Standard reference, fully sampled MSE phantom images were obtained to which M0 and T_2 maps were fitted on a pixel-by-pixel basis.

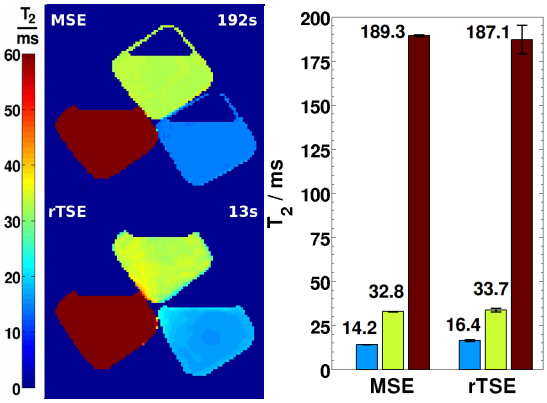

Fig. 1: *Comparison of T_2 Fit methods on a phantom*
MSE: pixel-by-pixel fit, fully sampled (TA = 192s)
rTSE: proposed method [3,4], undersampled (TA = 13s)
The bar chart shows mean values obtained from identical Regions of Interest along with the statistical error bars.

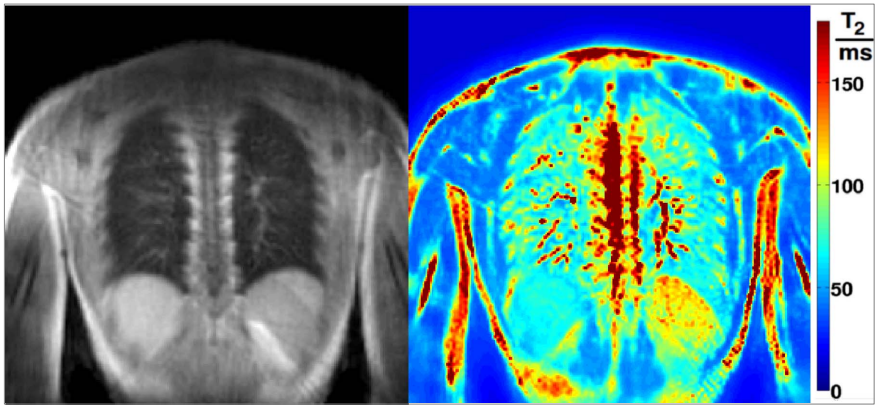

Fig. 2: *representative M_0 and T_2 map of a healthy volunteer acquired in 13s expiration period using undersampled rTSE and the proposed method [3,4]*

Results:

A comparison of parameter maps for the phantom is shown in Fig. 1. The acquisition parameters used were TR = 1.5 s, BW = 600 Hz/Px, ST = 10 mm and 128 readout points. 28 Spin-Echos were acquired with a 4.0 ms echo spacing, totalling an echo train length (ETL) of 112 ms. For rTSE-sampling, 224 Projections were acquired in total per slice. Fig. 2 shows one representative slice from a rTSE measurement taken of a healthy volunteer. Interleaved multi-slice data were acquired in a 13 s expiration period with 3.7 ms echo spacing and 6 slices. The remaining parameters were set as in the phantom measurement.

Discussion:

While accurate M_0 quantification requires a much longer TR to eliminate T_1 effects, the presented combination of undersampled radial TSE-based data acquisition with nonlinear inversion reconstruction shows potential for fast and efficient T2 quantification in the human lung. With 6 slices of 10 mm in thickness, a substantial fraction of the lung volume could be covered within a single breath-hold period. The phantom reconstruction using the proposed method shows good agreement with the fully sampled MSE reference. In the container with the fastest relaxation, T_2 is overestimated by 15% while consistent values are obtained in the containers with slower relaxation. For the volunteer measurement, obtained T_2 values in regions with little amounts of visible blood vessels are in a range of 55…75 ms, being in good agreement with literature values of 57…88 ms for the lung parenchyma during the systolic phase of the heart [8]. Future work will investigate the sensitivity of the proposed method for Asthma and COPD.

Acknowledgements:

This work was supported by the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology (BayStMWIVT), the Competence Network Asthma/COPD funded by the Federal Ministry of Education and Research (FKZ 01GI0881-0888) and Siemens, Healthcare Sector, Erlangen, Germany.

References:

[1] Hatabu, et al., Eur J Radiol 29(3): 245–252 (1999)
[2] Rasche et al., MRM 32(5): 629–638 (1994)
[3] Block et al, IEEE Trans Med Imaging 28:1759-1769 (2009)
[4] Sumpf et al., Proc. ISMRM, 2011, #2741
[5] Winkelmann et al., IEEE Trans Med Imaging 26(1):68–76 (2007)
[6] Völker et al., Proc. ISMRM, 2010, #2509
[7] Seiberlich et al., MRM 59(4): 930–935(2008)
[8] Hatabu, et al., Eur J Radiol 29(2): 152–159 (1999)