High resolution T2 weighted Lung Imaging with a radial Turbo Spin-Echo Sequence

M. Völker[1], P. Ehses[1], M. Blaimer[2], F. Breuer[2], and P. M. Jakob[1,2]
[1]Department of Experimental Physics 5, University of Würzburg, Würzburg, Bavaria, Germany, [2]Research Center for Magnetic Resonance Bavaria (MRB), Würzburg, Germany

Introduction:

MRI of the lung is still a challenging task due to its inherently low proton density, continuous movement caused by respiration and heartbeat, as well as a very short T2* relaxation time of roughly 1-2 ms at 1.5 T [1]. The latter of which can be overcome by using Spin-Echo type sequences which correct for additional spin dephasing owing to inhomogeneities at the numerous air-tissue interfaces within the lung, therefore being affected by the pure T2 decay only. Since standard Spin-Echo type sequences are generally slow due to their need for relatively long TRs, ultrafast single-shot sequences such as HASTE are preferred to freeze motion. However, resolution is intrinsically limited by the T2 decay. To increase resolution without suffering from motion artifacts, gating mechanisms accompanying multishot techniques like Turbo Spin-Echo (TSE) Sequences are therefore required. In this work, the feasibility of a radial TSE sequence [2] for high resolution lung imaging was examined under free breathing conditions without any triggering techniques towards its robustness to motion artifacts [2, 3]. It is demonstrated that quantitative T2 maps can be obtained from a single radial TSE acquisition.

Materials and Methods:

A segmented radial TSE sequence [2] was implemented on a 1.5 T clinical MR scanner. An adapted golden angle profile ordering scheme [4] was used to reduce both, motion artifacts and streaking artifacts due to non-uniform T2 weighting of the projections. The azimuthal step size was equal to the golden angle divided by the turbo factor TF, hence an angular section in k-space of the extent of the golden angle (111.246°) was evenly sampled after each excitation. Regarding only those profiles of one specific echo time TE, angular spacing was thus equal to the golden angle, yielding almost evenly distributed radial lines for each contrast. Data analysis was done retrospectively. 9 slices, each 5 mm thick, were acquired in an interleaved fashion. K-space was strongly oversampled using 2000 projections in total for each slice, each 256 Px in the readout direction. Sequence parameters were (FOV/ TE_{inter}/ TR/ TF/ BW) = 390 mm/ 4.4 ms/ 6000 ms/ 20/ 780 Hz/Px. Acquisition time was 10 min 6 s. Images were reconstructed using the Self Calibrated GRAPPA Operator Gridding (SC-GROG) algorithm [5] in order to shift the non-Cartesian data points onto a Cartesian grid. In order to yield different TE_{eff} from the 2000 projections, data were KWIC-filtered [6] highlighting the respective contrast of one specific echo time. A quantitative T2 map was calculated using a least square fit method applied on a pixel by pixel basis. Contrasts of all even echoes up to the 16th were used for the fit, providing 8 sampling points of the T2 decay curve before noise dominates signal intensity within the lung parenchyma.

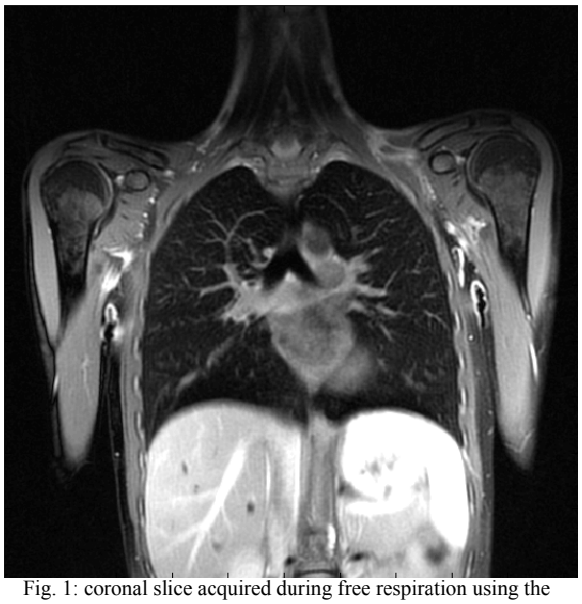

Fig. 1: coronal slice acquired during free respiration using the full 2000 projections. Nominal resolution: 1.5 x 1.5 x 5.0 mm³

Results:

Figure 1 shows a representative slice in coronal orientation reconstructed from the complete dataset (2000 projections), resulting in a mixed contrast of 20 echo times ranging from 4.4 ms to 88 ms. Only weak blurring can be seen in regions with negligible motion during the acquisition (upper lung) whereas strong blurring occurs in the heart, as well as in the lower lung and the diaphragm due to severe motion. However, due to the radial acquisition motion artifacts are predominantly spatially confined to their origin and do only marginally degrade overall image quality. Figure 2 shows examples of a proton density weighted image (a) and two images with different T2 weightings, respectively (b, c). They were obtained from KWIC filtering the data using only information of the 2nd (a), 10th (b) and 20th (c) echoes in the central k-space region. The T2 map (d) shows a distribution of T2 relaxation times with a mean value of 62 ms and a standard deviation of 12 ms within a 660 px² region of interest.

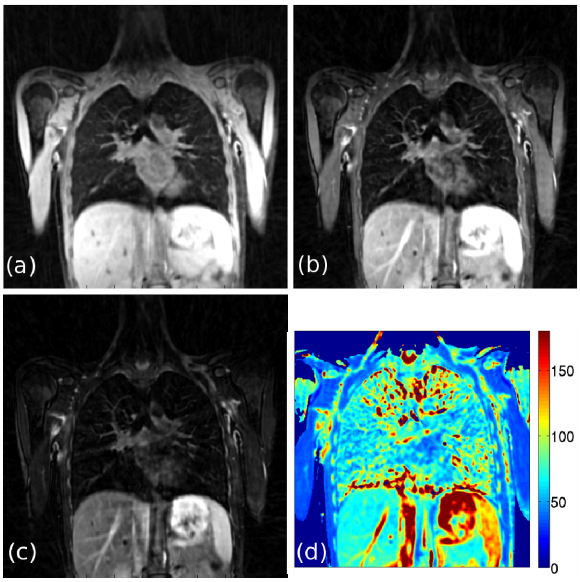

Fig. 2: KWIC filtered data from Fig. 1; TE = 8.8 ms (a), TE = 44 ms (b), TE = 88 ms (c); map of T2 in ms (d)

Discussion:

The presented radial TSE sequence provides a solid basis for lung imaging due to its robustness and minimum sensitivity to motion. With a single data acquisition it allows for high resolution proton density and T2 weighted lung imaging during free respiration at 1.5 T without being limited by the T2* or T2 decay. Since motion manifests only in local blurring no ECG triggering is necessary to image the lung, thereby improving acquisition speed and patient comfort. For improved motion correction, triggering or gating techniques may be applied offering increased resolution by reduced blurring. It has been demonstrated that variable T2 contrasts can be generated from a single dataset by applying a KWIC filter allowing to generating T2 maps of the lung. The accuracy is mostly affected by the low SNR and additional artifacts originating from the KWIC-filter itself.
In a next step self gating will be implemented to reduce blurring artifacts caused by respiratory motion [7]. A considerable improvement of effective image resolution is thereby expected.

Acknowledgements:

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