Fast T2 Mapping of the Lung within one Breathhold using Radial TSE Acquisition and PCA aided Image Reconstruction

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Introduction: Quantification of relaxation times in the human lung may offer diagnostic potential for Chronic Obstructive Pulmonary Disease (COPD). However, improving the capability of fast parameter quantification techniques for the clinical routine is especially challenging due to the poor signal properties of the lung. The inherently low proton density, very fast signal decay with a T_2^* relaxation time of roughly 1-2 ms at 1.5 T [1], continuous motion and blood flow complicate quantitative MRI. In this work, we present a strategy for quantification of the transverse relaxation time T_2 during a single breathhold. It is shown that multislice T_2 maps can be obtained by a combination of a radial Turbo Spin-Echo sequence [2] with a novel iterative reconstruction technique involving Principal Component Analysis (PCA).

Methods: A 2D multislice radial TSE sequence [2] was implemented on a 1.5 T clinical MR scanner. 7 slices with 10 mm thickness were acquired in an interleaved fashion within a breathhold of 11.5 s. With 10 excitations per slice and turbofactor TF = 22, a total number of 220 radial projections could be acquired at 22 echo times with 128 points in the readout direction. FoV was 380 mm, TR = 1050 ms. A modified golden ratio based view ordering scheme was used [3], yielding a nearly uniform distribution of projections with identical TE in k-space [4]. In a first step, the non-Cartesian data for each TE were shifted on Cartesian grids using GROG [5]. The resulting 22 sparsely populated k-spaces per slice were further processed using an iterative approach based on PCA [6] in order to reconstruct one artifact free image per TE. Prior to the actual reconstruction, training data were obtained by applying an FFT to the undersampled k-spaces and fitting an exponential decay to the magnitude images on a pixel-by-pixel basis. These training data represent the signal dynamics of the spin-ensemble and were used to determine a principal component basis with the PCA algorithm [7]. Fig. 1 depicts an incomplete time-series $S(k_x, k_y, TE)$ of one k-space point. After transformation into the eigenbasis, all coefficients have non-zero value (fig. 2). Since the relaxation dynamics resides within the first principal components, data above a certain coefficient may be set to zero. Transforming the filtered data back into the original basis (fig. 3) fills up the entire series of echo times with interpolated data based on the measured points in conjunction with the signal model implied in the training data. Keeping three principal components, this method was applied to the Cartesian k-spaces. To maintain data consistency, the measured data were reinserted and the process was iterated until convergence was achieved. A T_2 map was fitted on a pixel-by-pixel basis to magnitude images of the reconstructed time series.

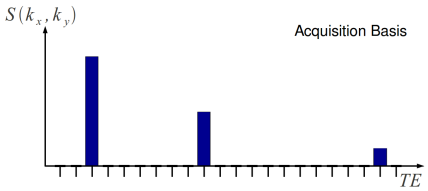

fig. 1: *incomplete times-series in one k-space point*

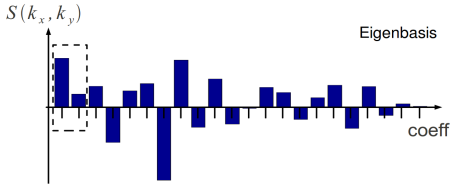

fig. 2: *representaion of the time-series in fig. 1 in the PCA-basis; only data in the dashed rectangle are kept*

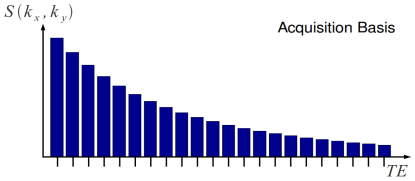

fig. 3: *back transformation of the filtered data in fig. 2 results in an interpolated signal evolution*

Results: rTSE data of healthy volunteers were acquired in an expiration period of 11.5 s. After PCA-based reconstruction, the contrast may be varied between short TE (proton- or T1-weighting) and strong T_2 weighting. Representative reconstructions for one of 7 slices are shown in fig. 4. A T_2 map was calculated using all 22 contrasts (fig. 5). For regions with little amounts of visible blood vessels the obtained T_2 values are in a range of 55…70 ms, being in good agreement with literature values of 57…88 ms for the lung during the systolic phase of the heart [8]. A drop of T_2 can be seen in the left lung with T2 ≈ 42 ms. This could be due to the oblique fissure between the upper and lower lobe.

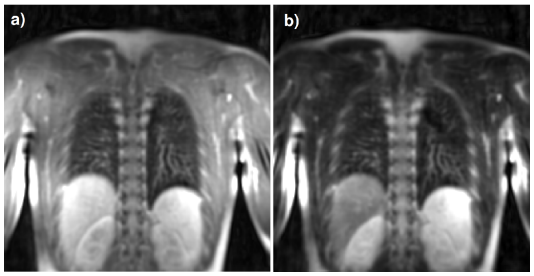

fig. 4: *Separated contrasts of one rTSE acquisition after PCA-based reconstruction; a) TE = 8.6 ms, b) TE = 94.6 ms; images are scaled to 50% of their respective intensity maximum*

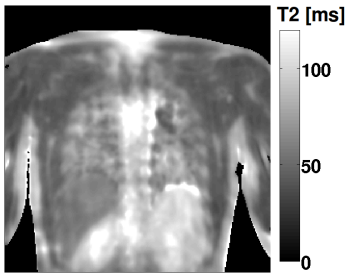

fig. 5: *T_2 map of one representative slice acquired in 11.5 s expirational breathhold*

Discussion: The presented combination of highly undersampled radial TSE-based data acquisition with PCA aided iterative reconstruction shows potential for fast and efficient T_2 quantification in the human lung. With 7 slices of 10 mm thickness almost the entire lung volume could be covered within a single breathhold. The obtained relaxation times are not only influenced by pure T_2 relaxation but are shortened due to perfusion of the lung [8]. Additionally, signal contributions from stimulated echoes may lead to an increase of the apparent T_2. The possibility of T_2 quantification in a clinically acceptable time frame may prove beneficial in diagnosis of lung diseases.

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