Radial MRI of the human lung

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Introduction

Magnetic resonance imaging of the lung is very challenging because of low proton density, cardiac and respiratory motion and susceptibility effects at large number of air/tissue interfaces on small scales. Thereby, the effective transverse relaxation time T_2^* of lung tissue is in the order of one millisecond [1].
Radial k-space sampling schemes provide very short echo times down to the submillisecond range. Furthermore, radial acquisition techniques are relatively motion insensitive due to central k-space averaging effects [2]. Thus, radial techniques should be well suited for lung imaging. Additionally, short readout times are feasible in radial MRI allowing the acquisition of a set of slices covering the whole lung volume within a single breathhold. In this work, a 2D radial gradient echo technique with angular undersampling was optimized for lung imaging and on-line data reconstruction was implemented.

Methods

Imaging of a healthy human lung was performed on a 1.5 T whole-body scanner (Avanto, Siemens Medical Solutions, Erlangen, Germany) with Siemens body and spine array coils using five receive channels. No contrast agent was applied. The k-space readout pattern consisted of a conventional 2D slice encoding and a radial in-plane readout with angular undersampling: P=384 angular projections by S=192 radial samples which resulted in k-space oversampling in the central region and undersampling in the periphery ($\Delta k_r > \Delta k_\varphi$ in fig. 1). The readout bandwidth was 94 kHz resulting in $T_{readout}$=2.0 ms/projection, T_{ACQ}=1.57 s/slice and in-plane resolution 0.9 mm. Further parameters were: acquisition of 15 slices with a thickness of 5 mm, FoV=350 mm, flip angle α=10°, TE=0.57 ms, TR=4.1 ms, Sinc RF excitation with a duration of 0.5 ms.
For comparison conventional Cartesian sampling was performed with a gradient echo sequence (matrix size of 320 and 3/4 partial Fourier) using TE=2.54 ms, TR=100 ms, flip angle=20°, bw=400 Hz/pixel resulting in a comparable total acquisition time of T_{ACQ}=1.6 s/slice.
For image reconstruction of the non-cartesian data, gridding on a Cartesian grid (matrix size: 384) was implemented according to [3] with a Kaiser-Bessel window function according to [4] and a linear precompensation weighting function that plateaus at 50% of the distance to the k-space periphery similar to [5]. On-line image reconstruction on the scanner was implemented in the Siemens Image Calculation Environment (ICE).

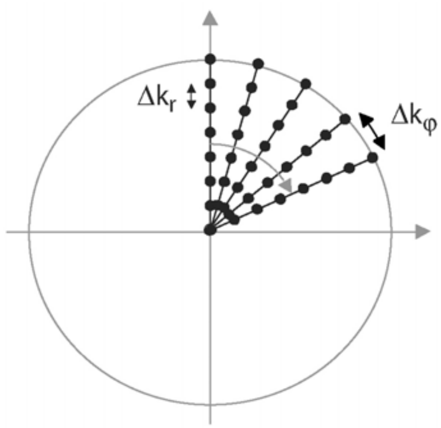

Fig 1. Schematic k-space trajectory of the radial in-plane readout pattern.

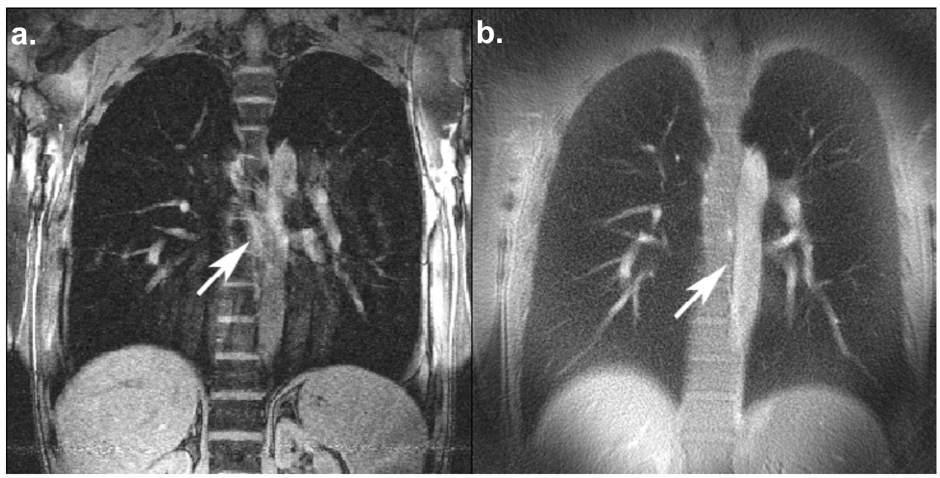

Fig 2. Images of the lung with different k-space sampling techniques: a. Cartesian acquisition, b. radial acquisition with significantly reduced motion artifacts (aorta descendence, arrows) and improved visibility of small vessels.

Results

Fig. 2 shows one examplary image slice of the Cartesian sampled data and of the radially sampled data respectively. In fig. 2a., motion artifacts caused by pulsation of the aorta descendence can be observed which are depressed in fig. 2b. In the radial image pulmonary arteries are visible down to the 4th generation which implies that the effective in-plane resolution is about 2 mm (compared to the theoretical value of 0.9 mm). Reconstruction times of the radially sampled data are in the order of 1-2 s/slice.

Discussion

Radial sampling significantly increases image quality due to reduced motion artifacts. Since T_2^* is very short (≈1 ms) in lung tissue, the use of very short echo times is beneficial. An echo time of TE=0.57 ms provided by the radial sequence yields substantially improved visibility of lung parenchyma and sub-segmental vessels compared to the Cartesian sampling with a four times larger echo time of TE=2.54 ms. Fast on-line image reconstruction provides prompt access to the images of the radial data allowing immediate diagnosis and easy handling in existing databases.

References

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