Towards Routine Lung MRI in Small Animals

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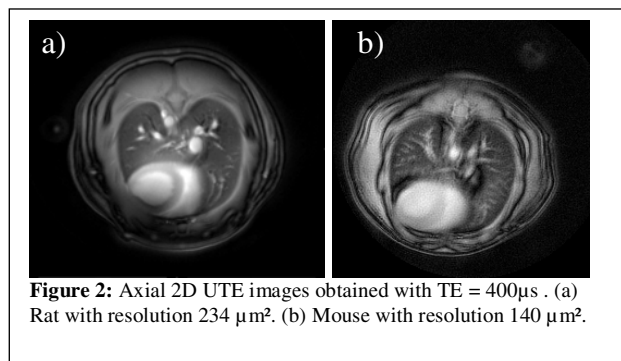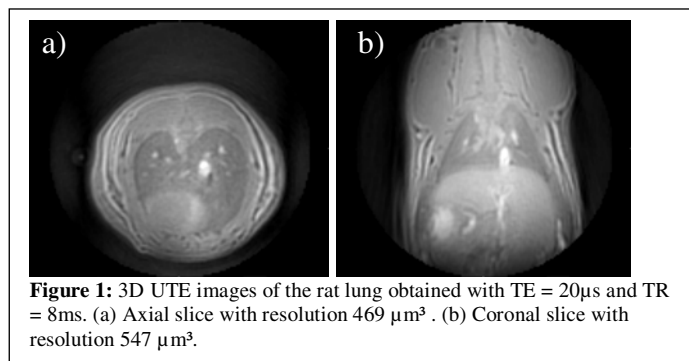
Introduction

Major challenges of magnetic resonance imaging of the lung are cardiac and respiratory motion and the low proton density of lung parenchyma. In addition, high susceptibility effects caused by the large number of alveolar air / soft-tissue interfaces lead to very short T_2^* relaxation times in the lung, calling for an imaging technique with very short echo times and fast data readout [1,2]. Radial acquisition techniques are relatively insensitive to motion due to frequent sampling of the central k-space [3]. Furthermore, radial schemes sampling the FID provide very short echo times down to the sub-millisecond range. Ultrashort echo times can be achieved using 3D or 2D UTE sequences, that limit the echo time to only the hardware switching time. However, the half-excitation approach used in 2D UTE is prone to errors from gradient imperfections and also doubles the scan time [4]. In this work, both 3D and 2D UTE were implemented with conventional excitation in order to provide robust imaging techniques for high quality lung imaging. The potential for the application in small animals is demonstrated, and the differences of the two approaches are discussed.

Methods

This study was performed on a 7.0 T 16 cm bore *PharmaScan*® system (Bruker BioSpin MRI GmbH, Ettlingen, Germany) equipped with transmit/receive volume coils of diameters 62 mm for rats and 38 mm for mice, respectively. The 3D UTE sequence was implemented with a non-selective RF excitation pulse followed immediately by a radial FID readout. Sampling is performed already on the gradient ramp and therefore starts always at the k-space center [5]. The endpoints of the radial projections follow rings on the surface of a sphere. TE is defined as the time between the center of the RF pulse and the start of the data acquisition. Using a block pulse of 20 μs duration a TE of 20 μs was achieved, including 10 μs for switching from signal transmission to reception. The 2D implementation uses a conventional slice excitation followed by slice refocusing with maximum slew rate of the gradient system in order to achieve minimum TE. The subsequent sampling of the FID is analogue to the 3D version. With a Gaussian RF excitation pulse of 300 μs a minimum TE of 400 μs was achieved, accounting not only for hardware switching but also the slice refocusing.

For 3D imaging, 51360 projections were acquired in 6:50 min without any gating using a TR of 8 ms. Further parameters were: flip angle α = 10°, readout bandwidth of 100 kHz, matrix size: 128 x 128 x 128. The 2D experiment was triggered by the respiration and ECG signal of the animal. Further parameters were: flip angle α = 20°, slice thickness of 1.5 mm, readout bandwidth of 100 kHz, number of projections: 804, matrix size: 256 x 256, scan time: approximately 3 min. Image reconstruction was fully integrated into the scanner reconstruction software, using density compensation and data interpolation onto a Cartesian grid with parameters optimized for efficiency [6].

Figure 1: 3D UTE images of the rat lung obtained with TE = 20μs and TR = 8ms. (a) Axial slice with resolution 469 μm³ . (b) Coronal slice with resolution 547 μm³.

Figure 2: Axial 2D UTE images obtained with TE = 400μs . (a) Rat with resolution 234 μm². (b) Mouse with resolution 140 μm².

Results

Figure 1 shows axial and coronal slices selected from 3D UTE datasets of the living rat. Due to the short TE of 20 μs no substantial signal loss is visible in the lung parenchyma. The lower signal intensity of the lung compared to the surrounding tissue is caused by a lower proton density. Although no respiratory or cardiac gating was used, motion artifacts are not a major concern in this data due to the inherent averaging effect of the method. In Figure 2 results of the 2D UTE technique are shown from the rat (a) and the mouse lung (b). Despite a significantly reduced lung signal due to the longer TE of 400 μs fine structures of the lung in small animals can still be visualized with high SNR. Images of the presented quality are obtained with very good reproducibility for both techniques.

Discussion

It was demonstrated that due to their short TE, robustness, and very good image quality the two related UTE techniques are suitable candidates for lung imaging in small animals. The 3D version offers full lung coverage in less than 7 minutes if no gating is used, with the lung signal being fully conserved. On the other hand, the 2D approach allows imaging targeted to the anatomical structures of interest and to a single or multiple time points of the cardiac cycle. Furthermore, for the suppression of motion artifacts the gated approach is usually superior to the intrinsic averaging, thus producing slightly sharper images. Based on these criteria for each application the more appropriate method can be selected.

For further animal studies the described techniques show the clear potential to enable the characterization of various properties of the lung, such as lung volume determination and T_2^* quantification of the lung tissue. On the long term, the ultimate goal is the detection of different lung diseases for extended physiological and pharmaceutical studies.

References:
[1] D.O. Kuethe et al., Mag. Reson. Med. 57:1058-1064 (2007)
[2] S. L. Gewalt et al., Mag. Reson. Med. 29(1):99-106 (1993)
[3] G.H. Glover et al., Mag. Reson. Med. 28:275-289 (1992)
[4] H.T.C. Nielsen et al., Magn. Reson. Med. 41:591-599 (1999)
[5] J. Rahmer et al., Mag. Reson. Med. 55:1075-1082 (2006)
[6] P. J. Beatty et al., IEEE Trans. Med. 24:799- 808 (2005)