Real-time Lung MRI of the Mouse

Amir Moussavi[1,2], Martin Uecker[1,3], Tilman Johannes Sumpf[1], Roland Tammer[1,2], Jens Frahm[1], and Susann Boretius[1,4]

[1]*Biomedizinische NMR Forschungs GmbH am Max-Planck-Institut fuer biophysikalische Chemie, Goettingen, Germany,* [2]*DFG Research Center for Molecular Biology of the Brain (CMPB), Goettingen, Germany,* [3]*Electrical Engineering and Computer Science, University of California, Berkeley, United States,* [4]*Klinik für Diagnostische Radiologie, Universitätsklinikum Schleswig-Holstein, Kiel, Germany*

Introduction: Mouse models provide unique opportunities to better understand the pathogeneses of various pulmonary diseases such as lung cancer, infections or inflammatory diseases. In-vivo MR imaging may significantly contribute to this research and to the development of new therapeutic approaches. However, the breathing rate of mice under routine anesthesia in our lab is about 50-90 breaths per minute, which is about 5 times faster than the breathing rate of humans at rest. In case of free breathing, the frequency is even higher and may become irregular. To the best of our knowledge, up to now cardiorespiratory gated signal averaging[1] (CR) or cardiorespiratory retrospective self-gating (RSG)[2] are the commonly used methods to acquire lung MRI in mice, both lacking the opportunity to monitor breathing irregularities or fast, single-events such as rapid short-term responses to medications.

Real-time MRI of the mouse lung requires a short acquisition time per image. Recently, a new method has been proposed for human real-time MRI combining highly undersampled radial FLASH with a nonlinear inverse reconstruction algorithm[3]. The goal of this study was to evaluate the potential of this technique for mouse studies, where a high spatiotemporal resolution is mandatory and the numbers of elements in radiofrequency (RF) coil arrays are much more limited. In this feasibility study, we performed MRI of the lung with the use of a single-slice radial FLASH sequence to visualize the pulmonary motion while breathing.

Material & Methods: Healthy female adult NMRI mice (n = 3) were anesthetized by isoflurane (1.75% in ambient air). The mice were intubated endotracheally and ventilated with a rate of 60 breathes per minute. T1-weighted data sets were obtained using a spoiled radial FLASH sequence (TR/TE = 4/1.215 ms, flip angle = 15°, FOV = 77.7 × 77.7 mm^2, spatial resolution 0.243 × 0.243 × 1 mm^3) at 9.4 T (Bruker BioSpin, Germany). Signal detection was performed by a 4-channel mouse coil array (Bruker BioSpin, Germany). 125 radial spokes (5 interleaved turns[4]) together with a nonlinear inverse reconstruction[5] allowed for an acquisition time per image of 100 ms. Hence, a series of 10 frames was obtained during one breath. Lung MRI data sets were acquired over a period of one minute to cover approximately 60 breaths.

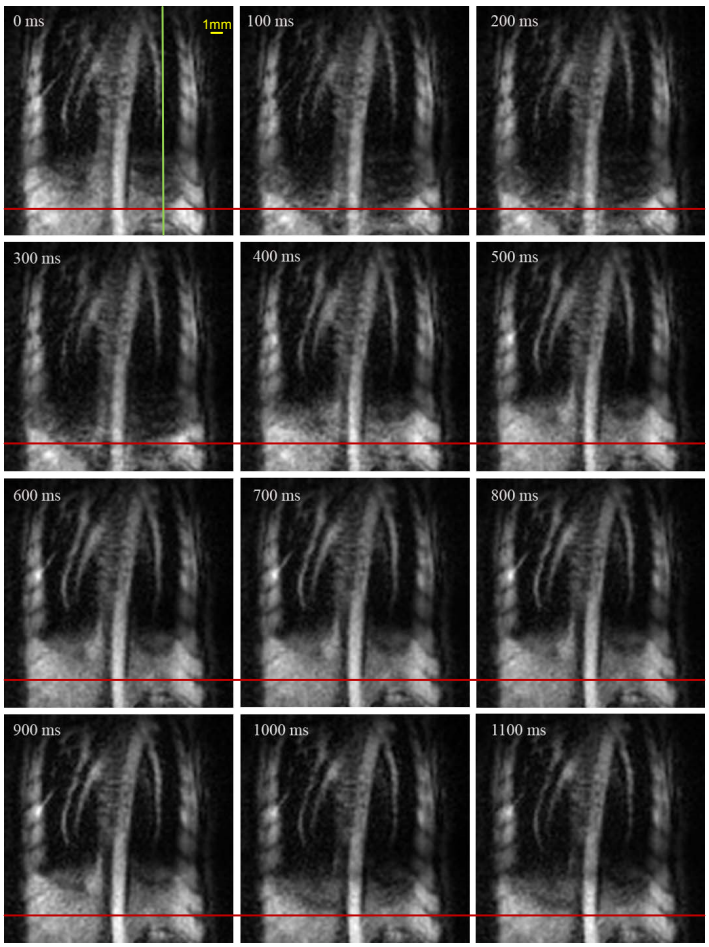

Figure 1

Results: Figure 1 shows consecutive images of a single breath. The reference line (red) shows the lowermost position of the diaphragm. The pulmonary up and down movement is clearly visible while breathing. Figure 2 (top) shows the time series of a selected column (green line in Figure 1) over the first 6 seconds. The breathing rate of 1 second per breath is apparent. The length of the lung was calculated and has been shown in Figure 2 (bottom). As expected, during inhalation the lung parenchyma enlarges and reaches its minimum at the exhalation phase. Irregular breaths (red arrow) during the acquisition can be easily excluded from pulmonary parameter estimation or separately analyzed. To address signal changes of the lung parenchyma, however, a reduction of the echo time has to be the aim of further sequence development in order to compensate for the short T_2^* at 9.4 T.

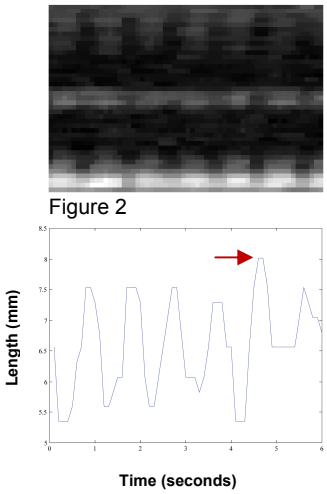

Figure 2

Conclusion: Highly undersampled radial FLASH MRI with nonlinear inverse image reconstruction allows for artifact-free imaging of the mouse lung in vivo. Volume and motion of the lung parenchyma could be analyzed with high spatial and temporal resolution. Moreover, the achieved speed does visualize different stages of the breathing mechanism which is in such a way not possible, neither by CR nor by RSG. Such real-time lung imaging may provide new insights into the function of the lung in health and disease. To overcome the low SNR of the lung parenchyma (short T_2^*) an ultra-short echo-time version of this method is currently under development.

References: [1] Togao et al. MRM 2010, [2] Zurek et al. MRM 2010, [3] Uecker et al. NMR in Biomedicine 2010, [4] Song et al. MRM 2000