Ultrashort TE MRI for Free-Breathing Imaging of the Rodent Lung

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Introduction

Among the challenges faced in pulmonary MRI are cardiorespiraotry motion, low signal, and magnetic inhomogeneities [1], making computed tomography (CT) the current standard for chest imaging [2]. Rapid radial MRI sequences, such as Ultrashort TE (UTE), can be implemented that takes advantage of the inherent motion insensitivity, short TE and high signal-to-noise [3]. In this work, we demonstrate a modified 3D UTE sequence for pulmonary imaging in mice that can be carried out under free-breathing conditions. By accurately measuring the radial trajectories, applying specialized view ordering and retrospective filtering radial data, high-resolution 3D images can be obtained without significant artifacts due to motion. Images can be collected at different points of the respiratory cycle allowing functional properties of the lungs to be measured.

Methods

Images were acquired using a Bruker 7T BioSpec small animal system and a 35 mm quadrature volume coil (Bruker BioSpec). All animals were anesthetized using 1.5% isoflurane in O_2 and the body temperature was monitored and maintained at 37 ^{o}C via heated air. 3D UTE sequence (TE = 0.02 ms, TR = 12 ms, FA = 5^{o}, projections = 115400, 266 µm isotropic resolution, scan time = 23 min) was used to acquire pulmonary images from mice without respiratory gating. Prior to each imaging sequence, trajectory mapping was implemented [4] and images were reconstructed using both prescribed and measured trajectories. Retrospective respiratory gating was implemented using MATLAB code that estimates the respiratory cycle by the change in the magnitude of the center points of k-space. Thresholding operations enabled separation of data collected at the end expiratory phase from the inspiration/expiration phase of the respiratory cycle, allowing reconstruction of images at two distinct respiratory phases. From the reconstructed images, the lungs could be segmented to extract functional information such as tidal volume and morphological changes during the respiratory cycle.

Results

A representative 3D UTE data set, reconstructed via regridding, using measured and prescribed trajectories is shown in Fig. 1A and 1B, respectively. The difference in the images is shown in Fig. 1C and shows a low frequency artifact centered in the image. By retrospectively filtering the data, images at two distinct respiratory phases can be reconstructed as shown in Fig. 2. This allowed segmentation of lung volumes at the two phases (Fig 3).

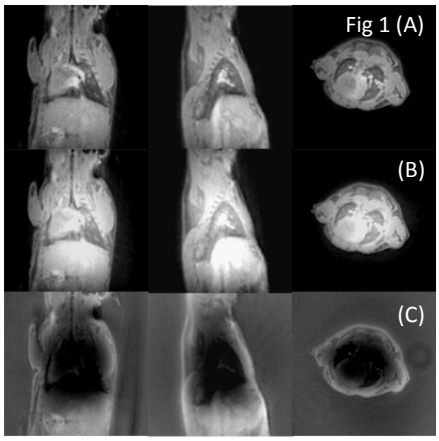


Fig 1: 3D UTE Reconstruction using measured (A) and prescribed (B) trajectories A subtraction of image B from A (C) demonstrates the dramatic effect that slight differences between the prescribed and measured trajectories make in the reconstructed image.

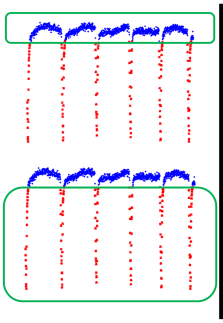
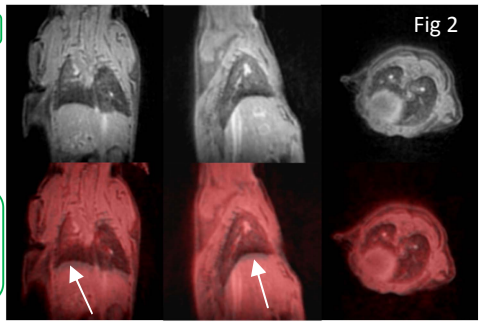


Fig 2: The change in the magnitude of the center point of k-space is plotted again time (right column). The blue region represents the end expiration phase of the respiratory cycle, and the red depicts the inhalation/exhalation phase. The image reconstructed with the inhalation/exhalation data (bottom in red) is overlaid onto image reconstructed with the end expiratory phase (top) to high-light the difference in the lung volume, as indicated by the arrows.



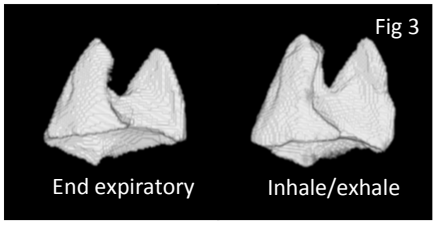


Fig 3: From the retrospectively respiratory gated images shown in Fig. 2, the lung volumes at two respiratory phases were semi-automatically segmented using MRIcron (http://www.mccauslandcenter.sc.edu/mricro/mricron/). These images provide morphological as well as functional information of the animal.

Conclusion We have demonstrated the utility of 3D UTE sequence for pulmonary imaging applications in mice. The importance of experimentally measuring k-space trajectories for image reconstruction is shown. The rapid 3D radial data acquisition allows for motion in-sensitive images to be acquired under free-breathing conditions and can provide valuable information regarding pulmonary physiology.

References

[1] Bergin et al. Thorac Imaging 1993. [2] Owrangi, et al. Respirology 2012. [3] Togao et al. MRM 2010. [4] Duyn, et al. JMR 1998.