Real-time MR imaging and tracking of regional lung motion during forced breathing maneuvers

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Introduction: A TurboFLASH sequence combined with parallel imaging is proposed for real-time imaging of the lungs during forced breathing maneuvers. High temporal resolution, real-time MRI acquisition of lung motion has been largely elusive (*1, 2*), though recent studies have demonstrated its feasibility (*3, 4*). Post-processing techniques using MRI for regional analysis of the pulmonary function have been reported using both intrinsic features (*2*) and grid-tagging MRI (*4*) for tracking parenchyma displacement. The goal of this study was to acquire images with high temporal resolution and a sufficient level of visible lung structure for parenchyma motion-tracking.

Methods: Imaging studies were conducted on a 1.5T Siemens Avanto scanner with maximal gradient strength of 45 mT/m and maximal slew rate of 200 mT/m/s. A TurboFLASH sequence was implemented with the following parameters: TR = 1.6ms, TE = 0.66ms, FA = 5º, matrix size = 128x128, 97% phase resolution, 75% asymmetric phase sampling, BW = 950 Hz/pixel. The parallel imaging technique GRAPPA with acceleration factor of two was used to further improve temporal resolution. Measurements were made in the coronal imaging plane with a 16mm slice thickness. Images were acquired in real-time at a rate of 10 frames per second during forced breathing maneuvers. Subjects were asked to take a series of normal breaths followed by maximal inspiration and maximal forced expiration – this procedure is identical to that performed in the pulmonary physiology lab. Data was processed using automated motion tracking software (*4*). Motion of intrinsic features (largely the pulmonary vasculature) was tracked between pairs of images using a cross-correlation algorithm (*5*). Images were evaluated with a two-step interrogation procedure; processing with four times oversampling yielded vector spacing of 8 pixels in both the x- and y-directions.

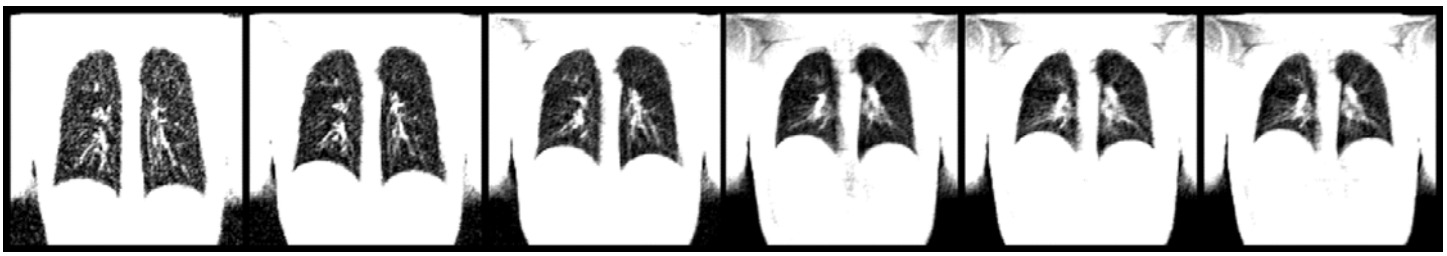

Figure 1. Series of six images of the thoracic cavity acquired in real-time during forced expiration, from maximum to minimum lung volume. Image acquisition rate is 10 fps; every fourth image is shown (t = 0.0, 0.4, 0.8, 1.2, 1.6, 2.0 sec). Images were windowed to highlight the level of contrast present in the lungs.

Results: MR imaging of forced breathing maneuvers was conducted successfully using a TurboFLASH sequence. In Figure 1, images are shown from a forced expiration experiment. Every fourth frame is represented, corresponding to times t = 0.0, 0.4, 0.8, 1.2, 1.6, and 2.0 seconds. The total forced expiration typically lasted about three to four seconds. A sufficient degree of the lung's intrinsic features were visible during the entire breath maneuver, making motion tracking of the parenchyma feasible. An exemplary plot of the tracking results is shown in Figure 2. Velocity vectors are overlaid on the original image: the color and vector length depict the magnitude of the instantaneous parenchyma velocity in cm/sec. The image time for this plot corresponds to the beginning of the forced maneuver.

Discussion: In this study, real-time imaging of the lung at 10 fps was demonstrated with forced breathing maneuvers. Forced maneuvers are typically difficult to capture with MRI due to the high temporal resolution needs and low contrast in the lungs. The 100-ms temporal resolution achieved in this work is the highest reported to date for proton lung imaging. Results from this work show sufficient structural detail in the lungs allowing use of established motion-tracking algorithms for analysis of lung function (*4*). This study demonstrates the potential for regional analysis of the lung while performing a full battery of pulmonary function tests.

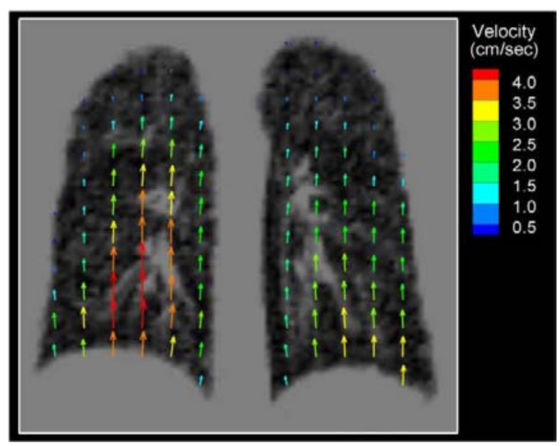

Figure 2. Velocity vector map of the lung during a forced expiration maneuver; time of image acquisition corresponded to beginning of expiration.

References

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