Assessment of lung function with simultaneous spirometric and grid-tagging MRI measurements

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Introduction: Non-invasive, regional assessment of pulmonary function has been demonstrated with the MRI-based spirometry technique (1). MRI spirometry uses grid-tagged images to dynamically track motion of the lungs during respiration. From displacement maps of the lung parenchyma, regional flow and volume change can be calculated. The technique has yet to be compared with conventional spirometry, in which the total volumetric air flow rate is measured through the mouth. The goal of this work is to validate grid-tagging MRI-based spirometry by conducting simultaneous spirometry and MRI measurements.

Methods: Simultaneous imaging and spirometry were conducted using a 1.5T Siemens Avanto scanner and a Korr pneumotach. The sequence, developed in-house *(1, 2)*, was implemented with the following parameters: TR = 1.85ms, TE = 0.66ms, FA = 5º, matrix size = 192x192, 75% phase resolution, 75% asymmetric phase sampling, BW = 955 Hz/pixel. Image acquisition time was 200 ms. Images with acquired in the coronal plane with a slice thickness of 16mm. A multiple-tag technique was used for continuous imaging over extended time periods, i.e. multiple breath cycles. Volunteers were asked to following a metronome to pace breath at 20 breaths per minute, quiet breathing. For this study, measurements were taken for approximately 60 seconds, or 20 breath cycles. Grid-tagging MRI-based spirometry was used to regionally quantify air flow and volume. Images were processed offline using software developed in-house with Matlab. From the grid-tagged images, total lung volume (per unit depth) was calculated by segmenting the lung/chest wall boundary. The post-processing analysis was fully-automated.

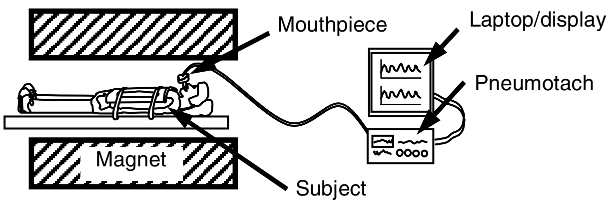

Figure 1. Schematic of experiment setup for simultaneous spirometry and MRI acquisition.

During image acquisition, total air flow rate was measured through the mouth using the Korr Medical Technologies RSS 100 Research Pneumotach System. Figure 1 shows a schematic of the experiment setup. The device was placed in the corner of the MRI suite, beyond 0.5 Gauss line to avoid magnet interference. An RS-232 output from the device ran through a wave guide to a laptop outside of the magnet room; the laptop recorded flow and volume at a rate of 50 Hz. Total volume (integrated air flow rate) measured from the pneumotach was compared to the segmented lung volume calculation. Note the segmented lung volume, which has units are per unit lung depth, really is a cross-sectional area measurement of the lung in the image plane. To account for this difference, the sum of the differences between signals was minimized to obtain a scale factor between the total lung volume and the segmented lung volume per unit depth. The scale factor is essentially a measure of the lung dimension in the image-normal, or anterior-posterior, direction. This dimension, measured from sagital images, was compared to the calculated scale factor. Four normal human volunteers were used for this study and proper informed consent was obtained.

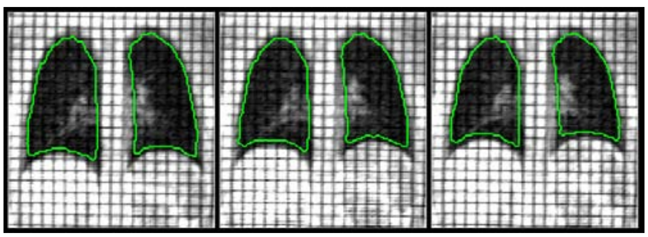

Figure 2. Segmented lung boundary from grid-tagged MR images for three time points from end-inspiration to end-expiration.

Results: Simultaneous MR image acquisition and pneumotach measurements were conducted successfully. Regional lung flow/volume and total lung volume per unit depth was calculated; exemplary plots of the segmented boundary of the chest wall are shown in Figure 2. Displayed in the figure are three points within a single breath cycle, from end inspiration to end expiration. The lung/chest wall boundary is designated by the green line. Lung volume per unit depth was calculated as the area within the segmented boundary. Results of the segmented lung volume compared to the total lung volume measured with the pneumotach are shown in Figure 3. The scale factor for this example was 15.2 cm. The anterior-posterior dimension of the lung measured at the sagital and coronal centerlines was 15.5 ± 1.0 cm.

Discussion: Results of simultaneous experiments show good agreement between volume measured using image segmentation and the pneumotach. Some error is believed to be due to the integrated volume output from the pneumotach, which has an auto-zeroing feature to handle air leakage from the pneumotach mouthpiece. If leakage does exist, a DC shift will appear from cycle to cycle. Quantitatively, there is excellent agreement between the scale factor and the true anterior-posterior dimension of the lung. In assessing regional function, it is also important that global function be measured. Incorporating the pneumotach with MRI provides a means for this to be achieved. More importantly however, results from this study show that total air flow rate and total lung volume can be extracted from segmented lung images, thereby rendering simultaneous pneumotach/MRI measurements unnecessary. This study validates a lung volume segmentation algorithm from which the overall performance, i.e. global function, of the lung can be determined in conjunction with MRI-based spirometry.

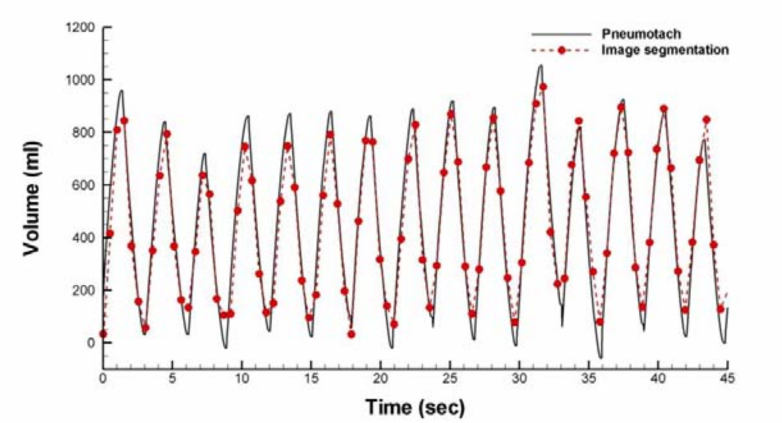

Figure 3. Volume vs. time plotted from pneumotach measurements and segmented lung volume calculation.

References

1. A. Voorhees, J. An, K. I. Berger, R. M. Goldring, Q. Chen, *Magnetic Resonance in Medicine* **54**, 1146-1154 (2005).
2. Q. Chen *et al.*, *Magnetic Resonance in Medicine* **45**, 24-28 (Jan, 2001).