MRI-based pulmonary function test using forced breathing maneuvers

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Introduction: The objective of this work was to develop a clinically viable protocol for conducting a region-based pulmonary function test (PFT) using MRI spirometry. Currently unavailable in the respiratory clinic, this non-invasive imaging test would provide physicians local information about lung function. It would not only serve to improve diagnosis of heterogeneous disease manifestations, but would also help guide surgical procedures such lobectomy.

An MRI-based pulmonary function test was developed using real-time acquisition of the lungs during forced breathing maneuvers and feature-based motion-tracking of the lungs. A high temporal resolution TurboFLASH sequence was implemented *(1)*, allowing sufficient capture of forced expirations with ~100 ms acquisitions. Deformation maps of the lungs were generated and used to calculate local volume change (2). Measurements from each test were internally validated by comparing regional volume change to total volume change in the lung, as calculated through segmentation (3). The results from this imaging test were presented to pulmonary physiologists using standard PFT parameters, yet on a regional basis.

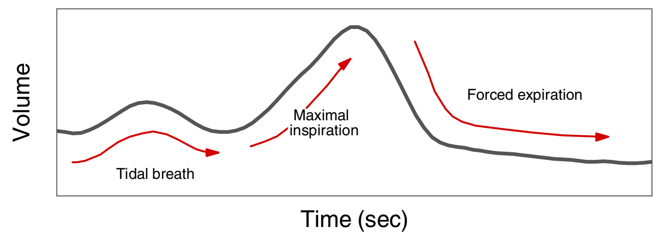

Figure 1: Typical forced breathing maneuver

Methods: Imaging studies were conducted on a 3.0T Siemens TIM Trio 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 = 0.77ms, FA = 5°, matrix size = 192x128, 67% phase resolution, BW = 965 Hz/pixel. Measurements were made in the sagittal imaging plane with a 16mm slice thickness. Images were acquired in real-time at a rate of 10 frames per second during quiet and forced breathing maneuvers. The breathing procedure was designed to match that performed in the pulmonary physiology lab – see Fig 1. Data was processed using automated motion tracking software (2). Motion of intrinsic features (largely the pulmonary vasculature) was tracked between pairs of images using a cross-correlation algorithm. 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.

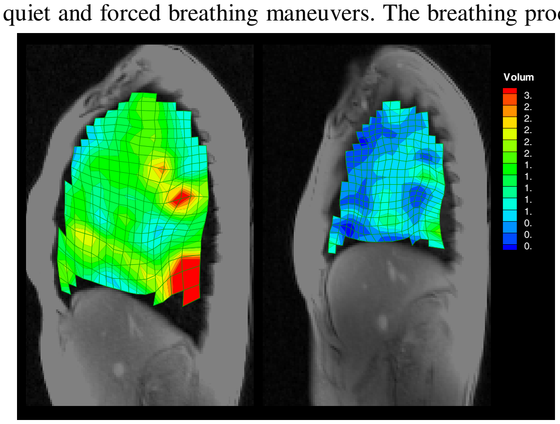

Figure 2: Regional volume contours for maximum and minimum volume

Results: Pulmonary function tests were performed in the MRI scanner uring realtime acquisition. Volume maps of the lungs, calculated from local deformation fields, were generated (Fig. 2). Local volume and flow were used to generate regional volume vs. time, flow vs. time, and flow-volume loops. A regional volume vs. time plot showing the lung divided into 19 regions is shown in Figure 3. PFT parameters, including FEV1, FEV6, FVC, and the time constant tau, were generated from the regional plots. These results were presented alongside conventional PFT results for comparison.

Discussion and Conclusions: Region-based pulmonary function tests have been shown to elucidate local dynamic phenomenon, previously unavailable in a non-invasive technique. Observed regional differences need to be examined in the context of a normal patient study and the potential to identify improved diagnostic measures for disease should be further evaluated.

References

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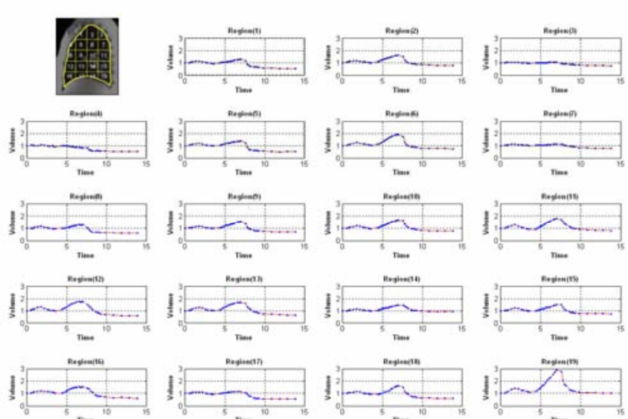

Figure 3: Regional volume vs. time plots