Assessing Local Lung Function: Measurement of Regional FEV1/FVC using Tissue Tracking MRI

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Introduction: The purpose of the present study was to use a real time tissue tracking MRI technique for the quantitative measurement of regional mechanics of the lung. By using a very short echo time (TE) and repetition time (TR), high frame-rate (10-frames/sec) MRI images capable of delineating *regional* lung structures (serving as intrinsic fiducial markers) can be acquired during forced inhalation and exhalation. These images can then be analyzed by tracking the local tissue motion to generate *regional regional* volume-vs-time curves. Physiological parameters related to *regional* airways resistance, such as *regional* (FEV_1/FVC), $FEF_{25\text{-}75\%}$ and time constant (τ), can then be obtained from these curves.

Methods: All studies were conducted on a 3.0T Siemens TIM Trio scanner. A gradient echo MRI sequence with very short TR/TE was implemented with the following parameters: TR/TE = 1.6ms/0.7ms, FA = 5º, matrix size = 192x128-192, with partial Fourier and rectangular field of view, BW = 965 Hz/pixel, 16mm slice thickness, 420-450 field of view. Measurements were made in both sagittal and coronal imaging planes. Images were acquired in real-time at rates up to 10 frames per second (fps) during forced breathing maneuvers. Subjects were asked to take a series of normal, tidal breaths followed by maximal inspiration and maximal forced expiration - a procedure that is identical to that performed in the pulmonary physiology labs for assessing global pulmonary function. Data were then processed using a custom motion-tracking software package (1). First, the boundary of the lung was identified from the 180-200 MRI images using a standard segmentation algorithm to obtain a lung volume-vs-time curve for the entire lung (Fig. 1). After that, local motion of intrinsic features (largely the pulmonary vasculature) inside the lung was tracked between image pairs using a cross-correlation algorithm (2). Images were evaluated with a two-step interrogation procedure; processing with four times over-sampling yielded vector spacing of 4 pixels in both the x- and y-directions. Local dilatation rate (i.e. volumtetric strain rate), calculated from the deformation fields, was used to obtain *regional* lung volume change over time curves (e.g. Fig. 2). Local FEV1/FVC values were then calculated from these curves based on the definitions illustrated in Fig. 1.

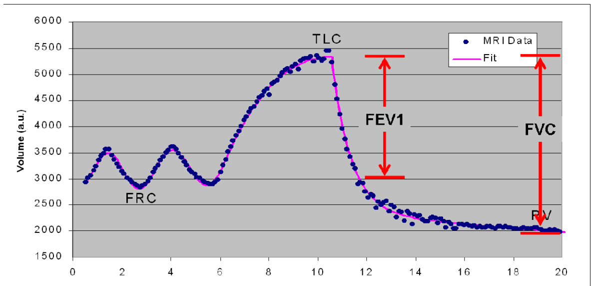
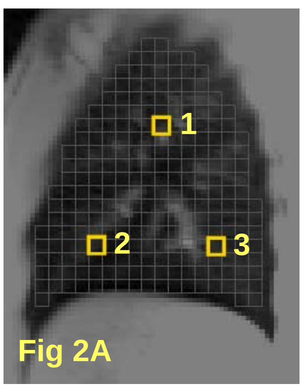


Figure 1

Results:



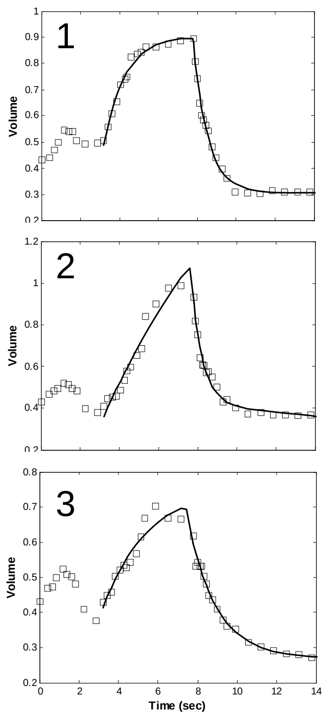


Fig. 2B

Figure 2. Three regions of the lung depicted in Fig. 2A were selected and used to show the volume vs. time curves depicted in Fig. 2B. These curves demonstrate the spatial heterogeneity of lung expansion during regular and forced respiration. The fitted curves were used to calculate FEV1/FVC values for the entire lung.

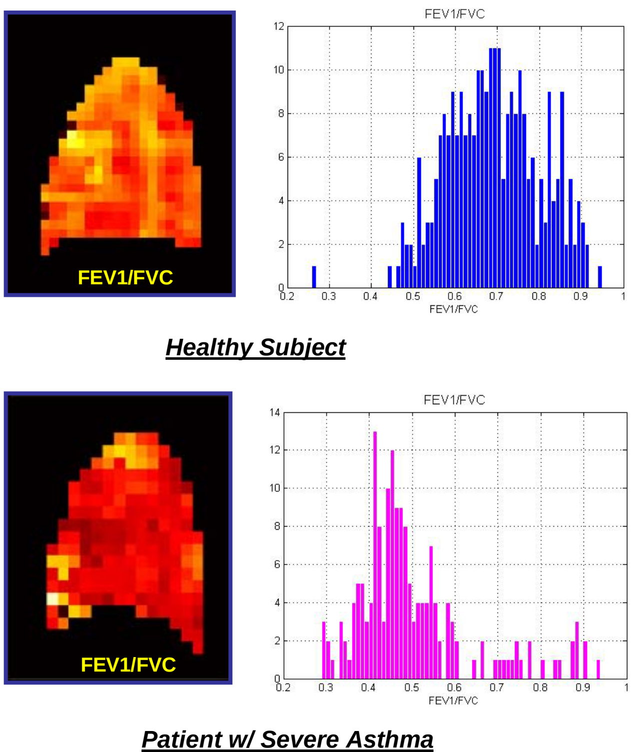


Figure 3. FEV1/FVC color maps (left) and histograms (right) obtained from a healthy volunteer (top) and a patient with severe asthma (bottom), demonstrating marked difference in local lung function.

Conclusions: We have shown the capability of using a real time tissue tracking MRI technique for the quantitative measurement of regional mechanics of the lung. Particularly, we have demonstrated that local FEV1/FVC can be measured on a regional basis, showing marked difference in local lung function between healthy subjects and patients with asthma. Such an assessment of airflow dynamics at the local level may provide a potentially very powerful tool for evaluating the contribution of peripheral airways to obstructive airway disease.

References: 1. Voorhees A, et al. Magn Reson Med 2005; 54:1146-1154. 2. Hsu T, et. al. Journal of Fluid Mechanics 2000; 410:343-366.