Voxel-based measurment of flow and volume using regional motion-tracking in the lung with hyperpolarized 3He MRI

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Introduction: Hyperpolarized gas and proton MRI have both been shown effective for assessing regional pulmonary function (1,2) . In this work, a novel method for measuring regional lung flow is presented that is based on motion-tracking of the lungs over a series of real-time hyperpolarized ^{3}He images. The automated algorithm (1) uses blood vessels (which appear dark) as markers to track lung motion during respiration. Gas flow can then be calculated from volumetric changes. These volumetric calculates of flow are relatively low resolution but can then be combined with signal intensity changes to measure flow on a pixel scale based on the assumption that signal change, when corrected for relaxation effects, is directly proportional to the air volume in the lungs.

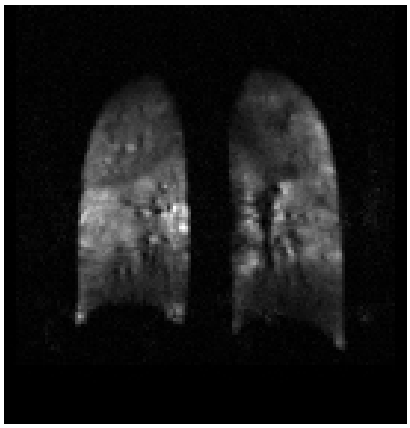

Figure 1: Exemplary ^{3}He image; 128x128 matrix, FOV 350x350 mm^2, TR = 3.8ms, TE = 1.9 ms, TA = 122 ms

Methods: ^{3}He was polarized by spin exchange with an optically pumped rubidium vapor to the level of 35-45% using GE Healthcare helium polarizers. Helium diluted with N_2 to a net polarization level of 12% was transferred to 1 liter Tedlar plastic bags and delivered to healthy human subjects. An unsegmented trueFISP sequence was used in conjunction with TSENSE to acquire the 2D data sets every 122ms (3). Studies were performed on a clinical whole-body 1.5T Siemens Avanto scanner using a 3×4×2 element phased-array coil built in-house (4). Data acquisition was performed over 10 seconds during a forced slow expiration of the inhaled ^{3}He, followed by a breathhold. Scan parameters were: TR 3.8ms; TE 1.9ms; parallel imaging acceleration rate 4; slice thickness 10 mm; 128 x 128 samples; field-of-view 350 x 350 mm^2. The temporal resolution of the images was 122 ms, and a series of 80 images were acquired. The slice was positioned coronally at the back of the lungs to avoid motion artifacts induced by the heart. Images acquired during the breathhold at the end of the acquisition were used to assess signal loss due to T1 and excitation effects and subsequently to correct for these effects in images acquired during expiration. Data was processed using automated motion tracking software (5). Motion of intrinsic features (largely the pulmonary vasculature) was tracked between pairs of images using a cross-correlation algorithm (6). Volume and flow were calculated both using the deformation map and signal intensity, as described above.

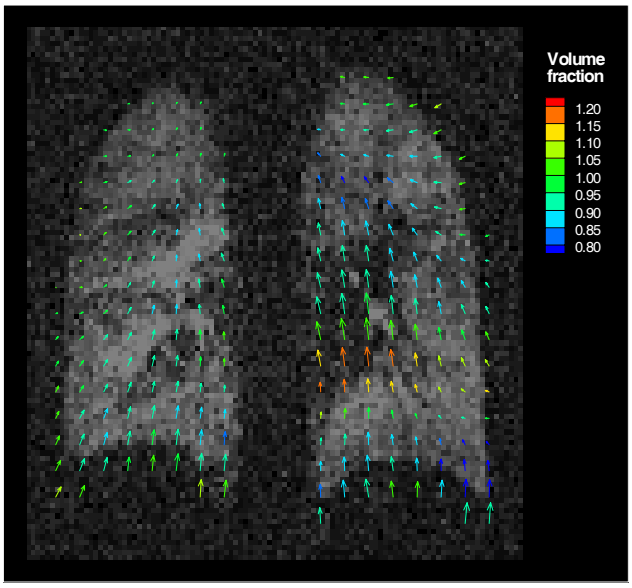

Figure 2: Regional deformation shown with displacement vectors, depicting lung deformation from the start of expiration; vector color represents regional volume fraction, as calculation from the Jacobian of the deformation matrix

Results: Figure 1 shows the first image of the set. The visible blood vessels are used for the motion-tracking, results of which are shown in Figure 2. Effectively, this provides a non-rigid registration of the lungs and allows for a measure of regional flow. The registration is also used to scale local signal intensity changes. The normalized plots of total volume change are shown in Figure 3, where good agreement between the rescaled signal intensity and volume is visible. The total volume change was about 5%.

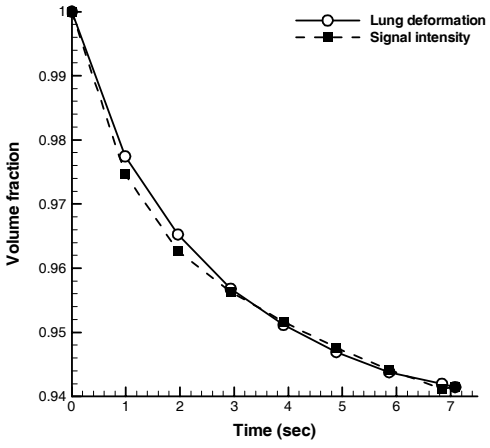

Figure 3: Normalized total lung volume (per unit depth) vs. time comparing volume calculated from both the deformation matrix and signal intensity; signal intensity linearly scaled using total volume calculation vs. time

Discussion and Conclusion: We have demonstrated a novel method of assessing air flow in the lungs on a pixel by pixel basis. Volumetric methods of measuring flow can be implemented using proton MRI. However ^{3}He MRI offers a number of advantages. First, no signal originates outside the lungs so that tracking at boundaries between static structures such as the chest wall and lungs is simplified. Second, volumetric changes can be combined with signal intensity changes to measure flow on a pixel scale. Finally, the regional lung capacity may also be calculated from the data.

References:

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