Comparison of Pulmonary ^{1}H non-contrast and Hyperpolarized ^{3}He MRI Ventilation Abnormalities in Bronchiectasis and COPD

Dante P Capaldi[1,2], Fumin Guo[1,3], Sarah Svenningsen[1,2], Weijing Ma[1,2], Khadija Sheikh[1,2], Roya Etemad-Rezai[1], Jonathon Leipsic[4], Harvey O Coxson[4], David G McCormack[5], and Grace Parraga[1,2]

[1]Imaging Research Laboratories, Robarts Research Institute, London, Ontario, Canada, [2]Department of Medical Biophysics, The University of Western Ontario, London, Ontario, Canada, [3]Graduate Program in Biomedical Engineering, The University of Western Ontario, London, Ontario, Canada, [4]Department of Radiology, University of British Columbia, Vancouver, British Columbia, Canada, [5]Department of Medicine, The University of Western Ontario, London, Ontario, Canada

Target Audience: Scientists interested in developing ^{1}H MRI methods to quantify pulmonary ventilation.

Purpose: Fourier decomposition of the free-breathing ^{1}H magnetic resonance imaging (FDMRI) has recently been used for non-contrast enhanced MRI to obtain regional pulmonary ventilation maps[1] by exploiting fast pulmonary MRI acquisitions of free-breathing ^{1}H MRI and non-rigid registration to compensate for respiratory motion. Spectral analysis of the images acquired using this method allows for identification of the respiratory frequency contributions.[2] While this work was previously performed on healthy volunteers and patients at 1.5T,[1] the method has not been optimized at 3T or in patients with severe chronic obstructive pulmonary disease (COPD) or bronchiectasis where respiratory rates have high variability. The objective of this study was to compare FDMRI with hyperpolarized ^{3}He MRI to visualize pulmonary ventilation abnormalities in bronchiectasis and COPD.

Methods: All subjects enrolled were previously diagnosed with bronchiectasis or COPD and provided written informed consent to the study protocol approved by the local research ethics board and Health Canada. Subjects were evaluated using hyperpolarized ^{3}He MRI, spirometry, plethysmography, 6 minute walk test (6MWT), St. George's Respiratory Questionnaire (SGRQ), thoracic CT and FD MRI. Dynamic free tidal-breathing MRI was acquired over a period of two minutes at a rate of four frames per second using respiratory bellows (to monitor patient respiratory patterns), an optimized bSSFP sequence (FIESTA), a 32-channel torso coil, and 3T Discovery 750MR (General Electric Health Care, Milwaukee, Wisconsin, USA) system. FDMRI of the free breathing ^{1}H signal intensity temporal fluctuations were used to generate a single coronal slice just posterior to the centre of the lung with the following parameters: 125s acquisition time, TE/TR/flip angle=0.616ms/1.898ms/15°, field-of-view (FOV)=40×40cm, matrix=256×256, NEX=1, and 15mm slice thickness. Hyperpolarized ^{3}He MRI static ventilation images were acquired within 5 minutes of FDMRI as previously described.[3] Non-rigid image registration was performed to compensate for respiratory motion using a modality independent neighbourhood descriptor (MIND) deformable registration technique that employs a local image descriptor as the similarity measurement and is optimized using Gaussian-Newton optimization approach with diffusion regularization.[4] The reference image was chosen so that the corresponding lung volume was consistent with that used in ^{3}He MRI static ventilation maps. Each image was deformed with respect to the reference image to maximize the geometric similarity between images. Pulmonary voxel intensities were aligned along a time axis and Fourier transforms were performed on the periodic voxel signal intensity fluctuation to determine the contribution of periodic breathing/ventilation to this periodic signal intensity pattern. Semi-automated segmentation was used to generate FDMR ventilation images that were compared with hyperpolarized ^{3}He MR images to identify regional relationships between FDMRI and hyperpolarized ^{3}He MRI ventilation abnormalities.

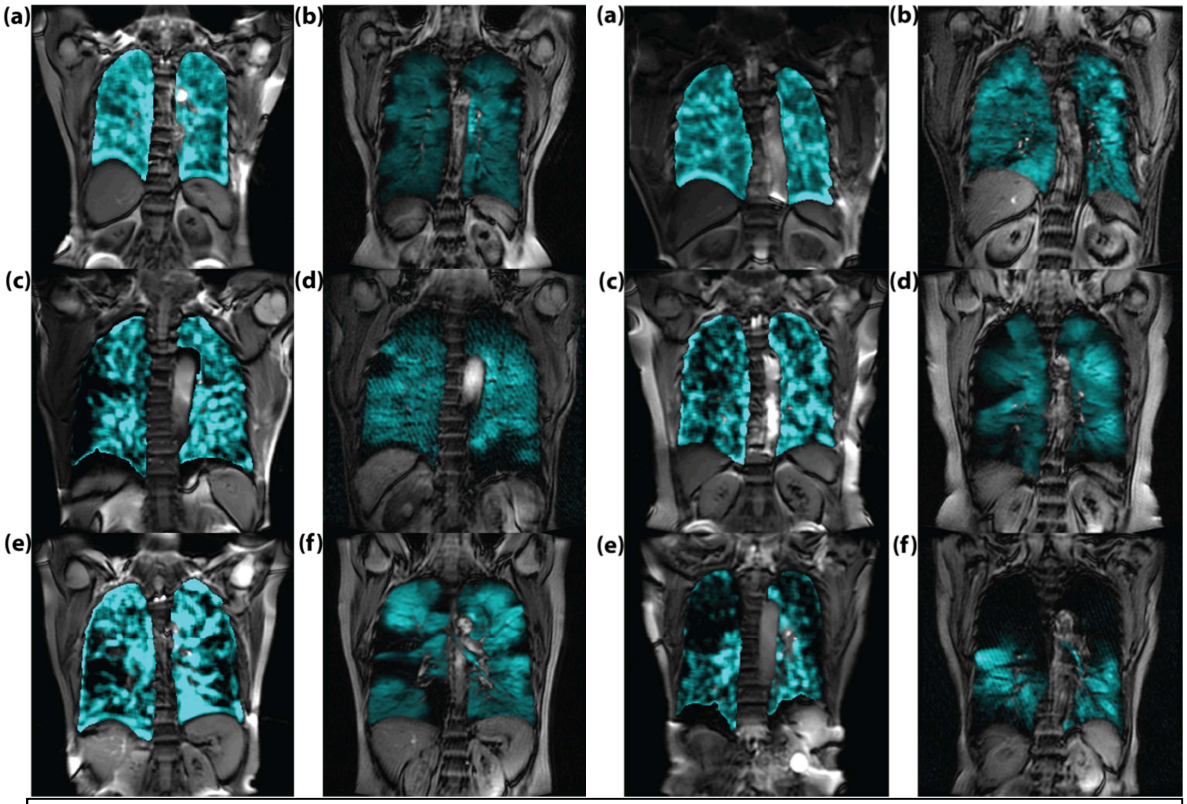

Figure 1. GOLD Stage I a) FDMRI, b) ^{3}He MRI; GOLD Stage II, c) FDMRI, d) ^{3}He MRI; GOLD Stage III e) FDMRI, f) ^{3}He MRI.

Figure 2. Mild bronchiectasis a) FDMRI, b) ^{3}He MRI; moderate bronchiectasis c) FDMRI, d) ^{3}He MRI; severe bronchiectasis e) FDMRI, f) ^{3}He MRI.

Results: Figure 1 shows three subjects with COPD at different stages based on the GOLD criteria (Stage I, Stage II, and Stage III).[5] Figure 2 shows three subjects with bronchiectasis at different levels of severity based on the CT evidence (mild, moderate, and severe). The spatial relationship of ventilation abnormalities (regions of signal void) between FDMRI and hyperpolarized ^{3}He MRI can be clearly identified for these subjects. Also, the magnitude of the ventilation abnormalities increases with the severity of the disease.

Discussion: Images generated using the FDMRI have the ability to detect ventilation abnormalities. These defects corresponded to those that were detected using hyperpolarized ^{3}He MRI. The FDMRI method may be improved by optimizing the pulse sequence and using a tailored deformable registration technique.

Conclusions: In this pilot study, preliminary results showed that FDMRI can be acquired using a 3T clinical scanner to provide pulmonary functional images highlighting regional ventilation abnormalities. Such functional abnormalities are shown to be spatially related to those found in static ventilation maps acquired using hyperpolarized ^{3}He MRI.

References: 1. Bauman G *et al. Magn Reson Med*. (2009); 2. Bauman G *et al. Magn Reson Med*. (2013); 3. Kirby M *et al. Acad Rad*. (2012); 4. Heinrich MP *et al. Med Image Anal*. (2012); 5. Vestbo J *et al. Am J Respir Crit Care Med*. (2013).