

Assessment of Repeatability of Hyperpolarized Gas MR Ventilation Imaging in Cystic Fibrosis Patients

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Introduction: Currently, the most prevalent outcome measures for cystic fibrosis (CF) are pulmonary function tests. Measured globally at the mouth, pulmonary function tests cannot provide information on regional lung function, information that is invaluable for detecting disease, staging disease progression, and assessing treatment efficacy. An innovative, non-invasive imaging technology, hyperpolarized (HP) gas MRI using ^3He or ^{129}Xe , can provide high-resolution information on pulmonary ventilation function on a regional level, without the need for ionizing radiation or chemical contrast agents. Because of its safety, its high resolution, and its capacity for imaging physiological function on a regional level, HP gas MRI offers great promise as an outcome measure for cystic fibrosis and other chronic pulmonary diseases. A key requirement for the use of this technology as an outcome measure is high baseline repeatability in individual subjects. Woodhouse et al. (2009) tested repeatability of HP ^3He MR images on five CF patients aged 6–15; they found that scans generally showed repeatability with the methods used, however, they did not use advanced quantitative analysis to quantitatively assess total lung ventilation, as was performed in the present study.

Methods: In this study, we examined the extent to which individual-level repeatability of ventilation characteristics were observed in HP ^3He MR images of five CF patients taken over a span of several weeks. The images were read by a pulmonologist who specializes in CF, and who has several years of experience with reading HP ^3He MR images. We performed HP ^3He static ventilation MRI scans on a Philips 3.0 Tesla Achieva MRI scanner using a flexible wrap-around ^3He radio-frequency (RF) coil (Clinical MR Solutions, Brookfield, WI) with a Fast Gradient Echo pulse sequence acquiring coronal multi-slice images with interleaved data acquisition and the following parameters: 45 cm FOV, 128×64 matrix, 15 mm slice thickness, TR/TE 135ms/1.5ms. Images were collected following a 10.9-second breath-hold after subjects inhaled a 1-liter bag of 300cc ^3He balanced with N_2 . Helium-3 was polarized to approx. 20% polarization by collision spin exchange at the time of imaging, using a custom-built polarizer. We calculated the ventilation volume of each slice from the ^3He scans using a semiautomatic segmentation algorithm (Lui et al. 2009). We also took the distribution of pixel intensities and compared them for each subject over the four imaging sessions.

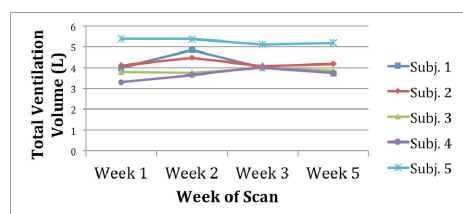


Fig. 1. HP ^3He MRI total ventilation volume in all subjects.

Results: Figure 1 shows total ventilation volume (VV) data for all subjects over the four scanning sessions. Note that numerically, the ventilation volume was relatively stable for all subjects except subject 1, who showed an increase in ventilation volume on her second scanning day. This increase in volume for subject 1 may have been due to an intensive exercise program the subject began between her first and second scan. Figure 2 shows HP ^3He MR images from a representative subject over the four different scanning

sessions. Within-subject HP ^3He MRI comparisons were not significantly different for total VV (one-way ANOVA, $p > .05$), whereas a within-subject analysis of the pixel-by-pixel signal from inside the lungs showed significant differences across days for the whole lung (one-way ANOVA, $p < .0001$) and for all four quadrants (one-way ANOVA, $p < .0001$).

Discussion: The HP ^3He MRI measurements were repeatable on the gross scale of total VV, but were not repeatable at the increased level of sensitivity inherent in the pixel-by-pixel signal analysis. Similarly, Kirby et al. (2011) found significant differences in ^3He MRI-derived ventilation defect volume numbers using a semi-automated ^3He ventilation segmentation tool. Our results indicate that, because of its high sensitivity and regional specificity, ^3He MRI has potential as a superior outcome measure for CF, but that the HP gas MRI community needs to evaluate the level of sensitivity to utilize when applying this technology to disease staging and therapy evaluation.

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References: Lui JK, et al. Proc. ISMRM 2009; Woodhouse, et al. J Magn Reson Imaging. 2009 Nov;30(5):981-8; Kirby M, et al. Acad Radiol. 2011 Aug;18(35):1006-13.

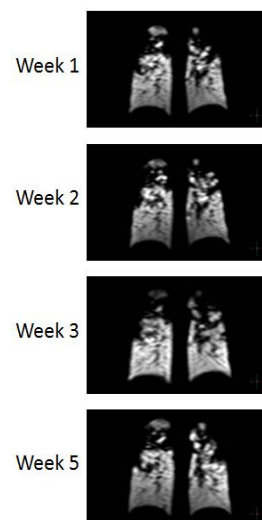


Fig. 2. HP ^3He MR images of a representative CF patient.