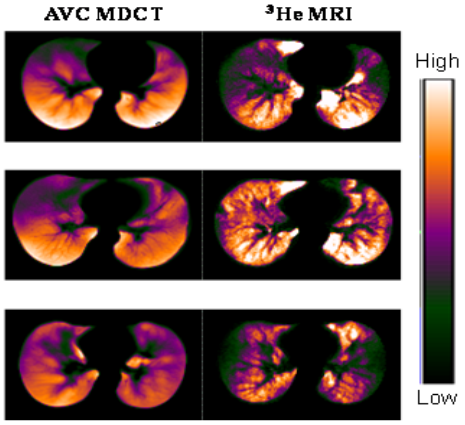
Validation of Hyperpolarized ^{3}Helium MRI in probing Regional Ventilation: A quantitative assessment against MDCT based local air volume changes (AVC)

A. F. Halaweish[1,2], Y. Yin[3], D. R. Thedens[1], C-L. Lin[3], E. J. vanBeek[4], and E. A. Hoffman[1,2]
[1]Department of Radiology, University of Iowa, Iowa City, IA, United States, [2]Department of Biomedical Engineering, University of Iowa, Iowa City, IA, United States, [3]Department of Mechanical & Industrial Engineering, University of Iowa, Iowa City, IA, United States, [4]Queen's Medical Research Institute, University of Edinburgh, Edinburgh, Scotland

Introduction Hyperpolarized ^{3}Helium (HP ^{3}He) noble gas imaging is a powerful tool in assessing the distribution of ventilation (static ventilation) and probing the underlying microstructure (apparent diffusion coefficient – ADC). The aim of this study was to assess the ability of these measures in quantifying regional ventilation via correlation against MDCT based regional ventilation measures obtained from matching FRC to TLC MDCT scans.

Methods 10 normal never-smoking subjects underwent pulmonary function testing (PFT) to verify classification of lung function as well as to establish lung volume inflation levels during imaging. MRI scanning was performed on a Siemens Avanto 1.5T (*2D FLASH @ 48.4676 MHz, 128 x 128 acquisition, 6 slices @ 15 mm, 22.5 mm inter-slice spacing, 2.5 x 2.5 mm pixels*), equipped with broadband capabilities, with the subjects centered inside the bore and fitted with a dedicated flexible ^{3}He-tuned transmit-receive radiofrequency coil (Clinical MR Solutions), while MDCT scanning was performed on a Siemens Definition 128 (*100mAs, 120kV, 512x512 acquisition, 0.6 x 0.6 pixels, 1.0 mm slices*). ECG, blood pressure and spO_2 measurements were monitored throughout the duration of the imaging sessions. Based on the subject's vital capacity (VC), control of lung inflation levels was achieved at FRC (~20%VC) and TLC (~100% VC), such that the HP ^{3}He lung volume levels matched those achieved during MDCT. A mass preserving image registration algorithm was applied to the FRC & TLC MDCT scans to estimate regional ventilation, while taking into account estimates of local tissue, air fractional content and minimization of tissue volume differences within the lungs. Regional ventilation maps were then jointly estimated from changes in local air fraction content along with the registration derived Jacobian values in the TLC image space. Segmentation of the MDCT scans was achieved via our in house software package PASS (*Pulmonary Assessment Software Suite*). HP ^{3}He ventilation (*sVent*) datasets were reconstructed from their respective raw-data files, segmented to exclude aliasing artifacts and large airways and sum normalized. ADC maps were calculated by fitting the baseline and diffusion weighted values to a mono exponential model to extract the diffusion coefficients, following noise filtering and segmentation. Matching of the MDCT regional ventilation maps @ TLC and the HP ^{3}He sVent & ADC maps @ TLC was achieved via rigid image registration (*Insight ToolKit*), utilizing the MRI datasets as the fixed image, while a down sampled dataset of the regional ventilation maps was used as the moving image. All datasets were masked to exclude background values to enhance the efficiency and accuracy of the image registrations.



	correlation	*slope*
ADC vs Jacobian	**0.6 - 0.83**	**0.65**
sVent vs sVol	**0.67 - 0.93**	**0.95**
sVent vs. Jacobian	**0.68 - 0.92**	**0.78**
sVent vs. airDiff	**0.76 - 0.92**	**0.91**

Results Four subjects analyzed showed strong positive correlations in a slice by slice assessment of HP ^{3}He sVent & ADC maps against the generated regional ventilation maps (*sVol – ratio of voxel volume changes over the air volume, airDiff – differences in air distribution as a function of Hounsfield unit changes, Jacobian – voxel deformation as a function of ventilation*), while the slopes of the regression lines also illustrated a strong positive linear relationship between the evaluated variables. ADC maps showed a strong correlation with regional estimates of lung deformation as described by the Jacobian maps of the image registration. Analysis of the correlation as a function of left & right lungs rather than whole lung also illustrated a positive correlation and a positive linear relationship between the functional measures.

Discussion We have demonstrated and verified the agreement between the MDCT based measures of regional ventilation and those achievable via HP ^{3}He MRI, illustrating a positive linear relationship between the two. When assessed on a more regional level, both MDCT and MRI based techniques demonstrate some dissimilarities, possibly arising from the gas density differences (helium *0.34 kg/m^3 vs. room air 1.2 kg/m^3*), leading to higher ventilation of ventral lung portions in the HP ^{3}He methods. Phantom studies have demonstrated that the rate of inspiration effects distribution of a dense gas (xenon) and similar effects for the lighter He gas will need to be explored.