Single Breath-hold, Whole Lung Morphometry with Hyperpolarized ^{3}He Using Parallel Imaging

Yulin V Chang[1], James D Quirk[1], Mario Castro[2], and Dmitriy A Yablonskiy[1]
[1]*Radiology, Washington University in St. Louis, St. Louis, MO, United States,* [2]*Medicine, Washington University in St. Louis, St. Louis, MO, United States*

Target audience Physicians and scientists interested in detecting and understanding lung diseases such as COPD and asthma.

Purpose The *in vivo* lung morphometry using the diffusion of hyperpolarized ^{3}He gas (1) has proven to be a powerful probe for detecting and understanding the mechanisms of lung diseases such as COPD (2). These diffusion measurements are based on 2D imaging of the lung with varying diffusion weightings (the "*b* values") (3) and are limited to partial coverage of the lung during a single breath-hold. When a multiple-channel receive coil is used, imaging can be accelerated by using parallel imaging techniques. Previously (4) it was shown that imaging of 2D slices can be significantly accelerated with little loss of accuracy in morphometry measurements using GRAPPA (5). In this work we develop 3D lung morphometry for whole-lung coverage in a single breath-hold.

Methods Lung morphometry data were acquired using a 1.5 T whole body scanner (Avanto, Siemens), a rigid volume transmitter RF coil and a flexible 8-channel receive array (Stark Contrast, Germany) arranged around the chest. ^{3}He gas was hyperpolarized to approximately 40% (Nycomed Amersham polarizer). Subjects inhaled 1 L of a 40/60 mixture of ^{3}He/N_2 from functional residual capacity and held their breath. A gradient-echo-based diffusion sequence was used for 3D imaging in the coronal view with parameters: 100 us, non-selective, 2.2˚ rectangular RF excitation pulse; TR/TE = 8.40/5.95 ms; bandwidth = 260 Hz/pixel; phase encoding lines centrically ordered as square spirals to optimize SNR; matrix size 64X40X16, resolution 7X7X14 mm^3, bipolar diffusion gradients (δ=1.5 ms, Δ=1.8 ms, ramp times=0.3 ms, b = 0, 2, 4, 6, 8, 10 s/cm^2) oriented along RO (head to foot, the direction the receive channels are not arrayed). *k*-space data were 2X under-sampled with 8 reference lines in each PE direction, leading to an effective acceleration factor of 3.2 and a total acquisition time of 10.1 s. Patient recruitment: The study was approved by the FDA and local IRB. Written consent was obtained from all subjects. Four subjects with asthma were imaged. For quality assurance one subject was imaged with both the proposed sequence and the conventional fully-sampled 2D sequence (3). Image reconstruction was performed in two accelerated dimensions in *k*-space (6). For each dimension, a 2D kernel of size [2 3] was used, where the 2 indicates one block from each side of the missing data and the 3 is along RO (7). The acinar airways radius (R), alveolar sleeve depth (h), and the mean linear intercept (Lm) were calculated according to (1).

Results Examples of the spin density (or b=0, top) images and the maps of the acinar airways radius (R, middle) and alveolar sleeve depth (h, bottom) of an asthmatic subject are shown in Fig. 1. Arrows indicate regions of elevated R values. For this subject, R=314±45 μm, h=127±55 μm, and Lm=216±53 μm. The same R maps in the axial view (bottom) are compared with their counterparts acquired by the traditional non-accelerated sequence in Fig. 2. Similar image qualities and parameters were obtained from the other 3 patients.

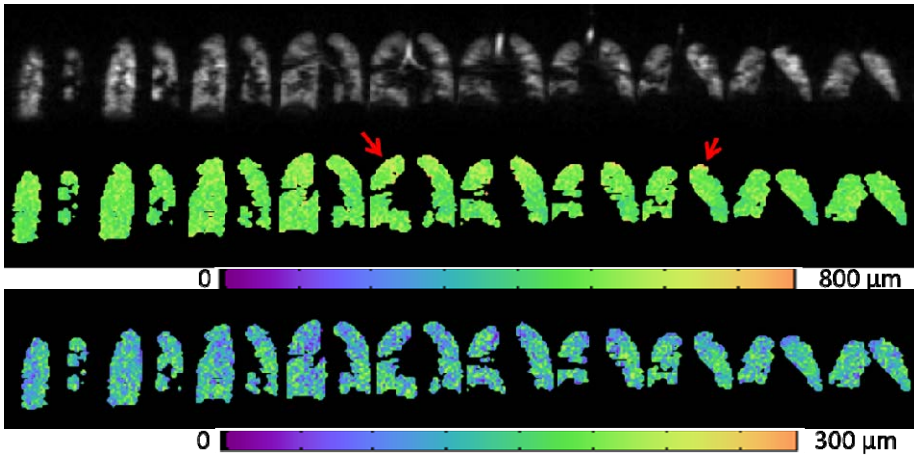

Figure 1 Spin density (b=0, top) images and maps of alveolar radius (R, middle) and alveolar sleeve depth (h, bottom) of an asthmatic subject. Arrows indicated regions of elevated values of R.

Discussion Evaluation of the acinar airways micro-structure over the entire lung is important in practice for detecting and characterizing heterogeneous lung diseases such as COPD and asthma. Whole-lung coverage improves the reproducibility of slice positioning, facilitating longitudinal studies of individual patients and patient-to-patient comparisons. In this study we took advantage of the localization of ^{3}He gas to the pulmonary tree and omitted the slab-selection gradient, thus significantly reducing the echo time and possible artifacts resulting from magnetic field inhomogeneities. This also allows reducing total imaging time to a single 10-second breath-hold. Further, by covering the entire lung all the HP ^{3}He in the lung was used for imaging with no waste of the expensive ^{3}He gas.

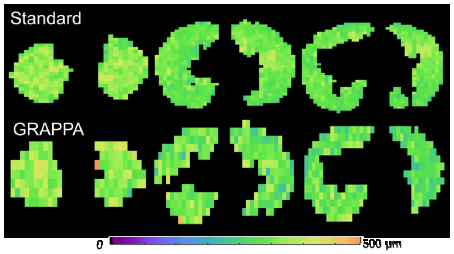

Figure 2 Comparisons of R-maps from standard non-accelerated sequence (top) and 2D accelerated imaging (bottom) in axial view.

Conclusion In this work we demonstrated that by using a multi-channel receive coil and parallel imaging techniques, lung morphometry can be measured over the entire lung within a single breath-hold and improved resolution.

References 1) Yablonskiy, et al. J Appl Physiol 2009;107:1258; 2) Quirk et al, Radiology 2011;260:866; 3) Yablonskiy, et al. PNAS 2002;99:3111; 4) Chang, et al. DOI:10.1002/mrm25282; 5) Griswold, et al. MRM 2002;47:1202 (6) Blaimer, et al. MRM 2006;56:1359; 7) Wang, et al. MRM 2005;54:738

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