Hyperpolarized-Gas Lung Imaging using a Single-shot Spiral Acquisition

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Introduction: Hyperpolarized-gas MRI using ^{3}He can provide quantitative information about lung structure and function. This noninvasive method is of great interest for studying lung diseases such as chronic obstructive pulmonary disease and asthma [1]. However, ^{3}He gas is expensive and its supply is limited. Thus, it is critical to improve the efficiency of ^{3}He gas usage and thus lower the imaging cost. In this study, we developed two single-shot spiral sequences towards that goal. In the first sequence, we used a preparation acquisition to obtain a field map before the imaging spiral readout. In the second sequence, we used a single-shot spiral with multiple gradient echoes. Ventilation and field maps are then estimated from the multi-echo data.

Methods: We developed two single-shot spiral sequences to obtain ventilation images of the lung using hyperpolarized ^{3}He gas as a contrast agent. Since the spiral readout time is very long (32 ms) for a single-shot acquisition, we need a field map to correct for inhomogeneity effects. In the first sequence, we introduced a preparation shot using a relatively small flip angle (30°) and a longer echo time to estimate the field map. Following the preparation, we used a 90° RF pulse to excite the remaining magnetization. The readout time is 32 ms for both the preparation and imaging shots. The sequence diagram is shown in Fig. 1(a). In the second sequence, shown in Fig 1(b), there is no preparation shot. Instead, we use multiple gradient echoes to estimate the ventilation image and field map jointly using a modified iterative algorithm based on nonuniform FFT [2,3]. We optimized several parameters to make the algorithm work, among which the number of time segments and the initial estimate of field map are crucial. The total readout time for the multi-echo sequence is 96 ms.

Both sequences were tested on healthy volunteers on a 1.5T Siemens Sonata scanner. The maximum gradient amplitude and slew rate used for the spiral readouts were 18 mT/m and 200 mT/m/s, respectively. The field of view was set to 40x40 cm in coronal views and 33x33cm in axial views. ^{3}He gas was polarized by collisional spin exchange with an optically-pumped rubidium vapor using a commercial system (Model 9600 Helium Polarizer, Magnetic Imaging Technologies, Inc.). All experiments were performed under a Physician's IND (# 57866) for imaging with hyperpolarized ^{3}He following a protocol approved by our institutional review board. Informed consent was obtained in all cases.

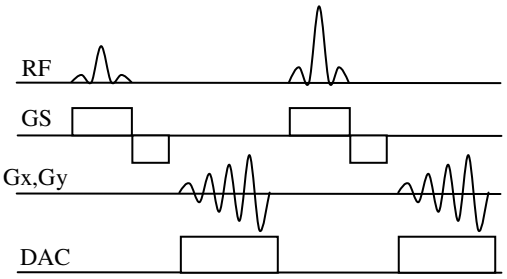


Fig. 1. (a) Single-shot spiral with a preparation shot

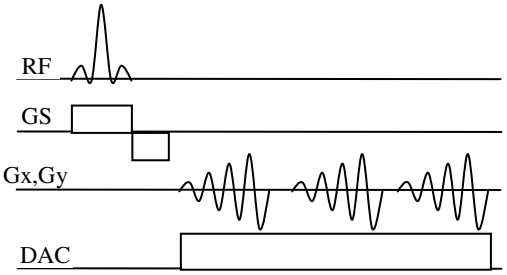
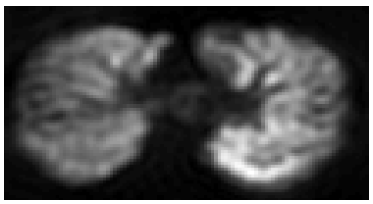


Fig. 1. (b) Multi-echo spiral

Results and Discussion: Representative imaging results from healthy volunteers are shown in Figs. 2 and 3. In Fig. 2, the data was collected using the first sequence with a preparation shot to obtain the field map. The image in Fig. 2(a) was reconstructed without using the field map while the image in Fig. 2(b) was deblurred using the semi-automatic off-resonance correction method [4]. We see that inhomogeneity artifacts have been reduced substantially in the deblurred image. In Fig. 3, the data was collected using the multi-echo sequence. Fig. 3(a) shows the image reconstructed using gridding without a field map. Fig. 3(b) shows the deblurred image reconstructed using the modified iterative algorithm. The number of time segments used was 19 and the number of iterations was 10.

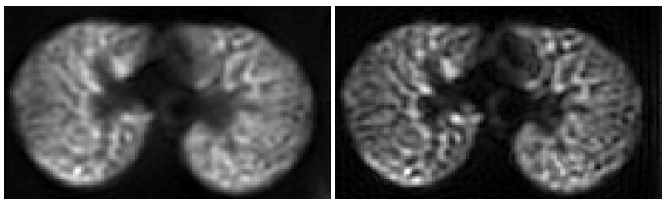
Conclusion: We developed two single-shot spiral sequences for lung imaging using hyperpolarized ^{3}He. Both sequences yielded reconstructed images with spatial resolution and image quality comparable to standard GRE images. We have begun experiments with parallel single-shot spiral imaging using a 24-channel coil array, which yields higher spatial resolution.

References: 1. Sean B. Fain et al JMRI 25:910–923 (2007). 2. Sutton, B.P. et al. MRM 51(6): 1194-1204 (2004).
3. Sutton, B.P. et al. ISMRM 10: 1323 (2002). 4. Chen W. et al. ISMRM 15: 3435 (2007).



(a) Without debluring (b) Deblurred image

Fig. 2. Reconstructed images using the first sequence



(a) Gridding result (b) Iterative reconstruction result

Fig. 3. Reconstructed images using the second sequence

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