Tagged Helium-3 MRI Analysis for Pulmonary Kinematic Quantitation

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Purpose

Recent innovations in hyperpolarized helium-3 magnetic resonance imaging include the employment of MR tagging techniques for assessment of pulmonary deformation [1,2]. Historically, such tagging methods have been successfully applied to cardiac research inspiring the development of advanced computational techniques for the quantitative analysis of myocardial deformation. The purpose of the present work is to apply these sophisticated analysis techniques to calculate kinematic quantities, such as displacement and strain, in the lung.

Methods

Two subjects participated in a feasibility study. Subject 1 was a normal male. Subject 2 was a female who had previously undergone right lung transplant for advanced pulmonary fibrosis, and thus had a normal right lung and a fibrotic left lung. MR imaging was performed using a 1.5 T whole-body scanner (Siemens Sonata), and helium-3 gas was polarized to approximately 40% using a commercial system (Model 9600, MITI). Following inhalation of a 1 L mixture of ~400 ml hyperpolarized helium-3 and ~600 ml N_2, 3-D tagging grids were created at breath hold by applying sinc-modulated RF-pulse trains consecutively along all three principal axes. Tag spacing was 28 mm. The grid-tagging preparation was applied first, followed by a FLASH-based 3D image acquisition at full inspiration with the following parameters: TR/TE = 2.0/ 0.7 ms; FOV= 340x280x198 mm; matrix = 64x64x22; flip angle = 1°. The subject was then instructed to exhale completely, and the FLASH-based acquisition was repeated following a pause of 2-3 s. Total scan time is 7.4s. The short TE of the FLASH sequence was achieved by using the asymmetric readout, yielding a partial k-space acquisition.

Post-processing was required for extraction of kinematic measurements. Initial detection of candidate tag line points was facilitated by a Gabor filter bank segmentation algorithm [3]. Subsequently, a parameterized matching between tag line points for consecutive time frames was generated using a fast B-spline scattered-data approximation algorithm [4]. The entire algorithmic pipeline was developed using the Insight Toolkit [5] for open-source dissemination. From this parameterized model kinematic information is obtained and deformation and strain fields can be visualized.

Results

Mid-coronal results for Subject 1 and Subject 2 are visualized in Figure 1. Summary displacement field statistics were calculated for Subject 1 (right lung: 13.4 ± 3.7 mm, left lung: 16.4 ± 4.2 mm) and Subject 2 (right lung: 16.1 ± 7.1 mm, left lung: 6.9 ± 8.0 mm). Summary principal strains were also calculated for Subject 1 (right lung: 0.1 ± 0.07, left lung: 0.1 ± 0.7) and Subject 2 (right lung: 0.09 ± 0.1, left lung: 0.02 ± 0.03). Compared with Subject 1 as well as the healthy right lung of Subject 2, the fibrotic left lung of Subject 2 demonstrates a decrease in deformation consistent with expected reduced pulmonary compliance.

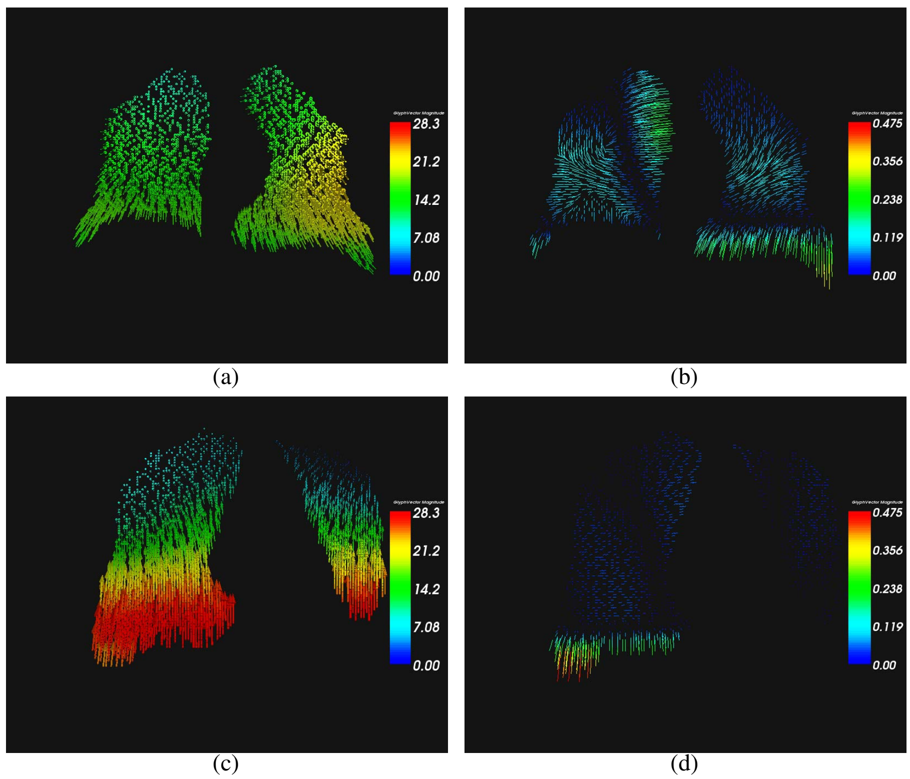

Figure 1: (a) Mid-coronal displacement for Subject 1 and (b) corresponding principal strain field. (c) Mid-coronal displacement field for Subject 2 and (d) corresponding principal strain field. The color bars represent, respectively, the magnitude of displacement in mm and the amount of deformation in images. Note that the subject with the fibrotic left lung shows decreased deformation at exhalation.

Conclusions

Tagged MRI using hyperpolarized helium-3 has potential over conventional tagged MRI in the lung for pulmonary mechanics research due to the sparsity and limited spatial resolution of the intrinsic anatomical features of the lungs. We have provided sample quantitative and visual results which illustrate the feasibility of our analysis methodology and demonstrate the ability to distinguish differences in the kinematics of normal and fibrotic lung.

References

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