Real-Time MR Imaging of Pulmonary Gas-Flow Dynamics with Hyperpolarized ^{3}He

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INTRODUCTION

MR studies of the human lung with hyperpolarized ^{3}He have demonstrated the potential to acquire high-resolution, *but static*, images of lung ventilation [1-3]. Given the high signal available from hyperpolarized noble gases, this method also potentially presents the opportunity to image, for the first time in real-time, the pulmonary gas-flow dynamics. An initial attempt to image gas dynamics in the human lung, based on a fast gradient-echo pulse sequence with a temporal resolution of 1 s, depicted inspiration as an "instantaneous uniform signal" in the lung, and expiration as a slow signal decay [4]; the dynamics of the inflowing gas were not captured. We report here on our attempts to image the dynamics of the inflowing gas by using a controlled breathing maneuver and faster pulse sequences.

METHODS

Imaging was performed on a 1.5 T whole-body scanner (Vision, Siemens Medical Systems, Iselin NJ), modified to operate at 48 MHz by the addition of a broadband RF amplifier and a ^{3}He Helmholtz-pair RF coil. Two sequences were investigated. First, an interleaved echo-planar imaging (I-EPI) 2D gradient-echo pulse sequence was used with the following parameters: TR/TE 15.2/8.0 ms, echo train length 5, FOV 53 cm x 70 cm, matrix 100 x 256, flip angle 5°. The imaging time per section was 0.32 s. (Note that due to diffusion-based-signal losses, single-shot EPI is not a suitable method to use with hyperpolarized ^{3}He.) Second, an interleaved spiral 2D sequence was used with the following parameters: TR/TE 15.2/2.5 ms, 16 interleaves with 4 turns each, FOV 50 cm, matrix 128 x 128, flip angle 5°. The imaging time per section was 0.24 s. For both sequences, images of one thick section (5 cm) were acquired continuously for 10-15 s.

Dynamic image sets were acquired from three healthy volunteers after obtaining informed consent. For each set, the volunteer slowly inhaled 1 liter of ^{3}He (polarization ~15%) over approximately 10 s. A coronal image set was positioned to include the trachea and main bronchi.

RESULTS

With both pulse sequences, gas could be visualized in the trachea and main bronchi before reaching the lungs. The left and right lungs filled over a period of 1-2 s.

Motion artifacts were substantially worse with the I-EPI pulse sequence. Considering the well-known susceptibility of I-EPI sequences to motion, and the fact that no specific forms of motion compensation were employed, this result is not unexpected.

With the spiral sequence, some areas of the lung parenchyma were well visualized whereas others appeared distorted from susceptibility effects. No corrective strategies (e.g., the use of field maps) were employed in these preliminary studies. Using well-established corrective measures, we anticipate that the image quality from the spiral sequence will be substantially improved.

Figure 1 shows 15 images from an interleaved spiral acquisition at 0.24 s intervals. In this image set, we can see gas filling the trachea and main bronchi in the first 1 s, and then filling the lung over the next 2 s.

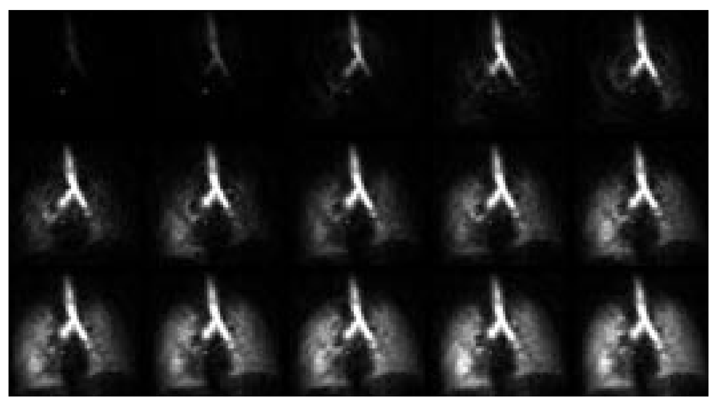

FIG 1: Interleaved spiral images at 0.24 s intervals.

CONCLUSIONS

These preliminary results demonstrate the potential for real-time imaging of pulmonary gas-flow dynamics with hyperpolarized noble gases. With improvements in the imaging technique increased temporal resolution and decreased image artifacts are expected. This methodology has the potential to provide new information on the physiology of lung function, and may contribute to the understanding and evaluation of some lung diseases.

REFERENCES

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