Hyperpolarized Helium-3 spiral ventilation imaging: Implementation and validation of a free-breathing protocol on a clinical MR scanner

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Introduction:

In human ventilation studies using HP Helium-3, the inhalation of gas is controlled by the patient and can be adapted to the imaging protocol: forced inspiration or expiration, duration of hold breath, inspired volume, etc. However in some particular circumstances, the patient might not be able to comply with a given protocol. This situation can be due for example to the patient unconsciousness, to reduced capacities or to its young age. In this study, we propose a ventilation imaging protocol designed for free-breathing. The protocol was implemented on a clinical scanner. Validation on rabbit and analyses of Helium-3 signal dynamics for the extraction of ventilation parameters are presented here.

Methods:

Experiments were performed on a 1.5T clinical MR scanner (Sonata, Siemens Medical Solutions, Erlangen, Germany) using an elliptic birdcage coil (RAPID Biomedical, Rimpar, Germany) for Helium-3 imaging, designed for human studies. Helium-3 was polarised using an in-house spin exchange optical pumping system.

The animals (3kg EOPS Rabbit) were anesthetized with an intravenous injection of a ketamine-xylazine mixture. A commercial animal mask was fixed on the rabbit head and carefully taped to avoid gas leaking. Once the animal positioned in the magnet, a reservoir filled with 200ml of polarized Helium-3 was screwed on the animal's mask and the imaging sequence was triggered. A spiral sequence was used with the following parameters: 24 interleaves; TR/TE =50/2.5ms; 256*256 Matrix; 158mm FOV; 10-50mm slice thickness; 10° Flip Angle. K-space was scanned continuously for a total acquisition time of 24s.

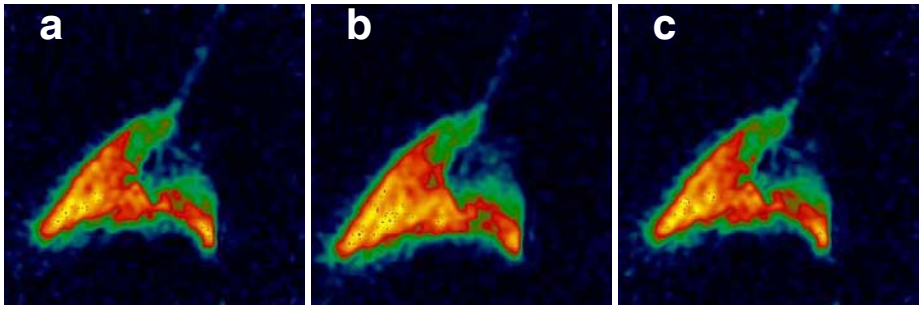

Figure 1: Free breathing He3 ventilation images of a rabbit at (a) early inspiration, (b) maximum of inspiration and (c) expiration phase.

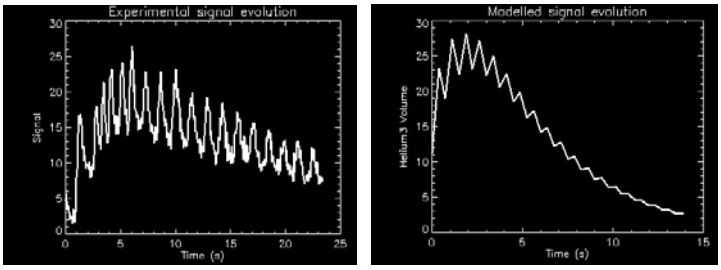

Figure 2: Signal evolution – (left) experimental results and (right) modeled evolution.

Results:

A dedicated spiral reconstruction program was developed using IDL (Boulder Colorado, USA) [1]. The ventilation images were reconstructed at different moments of the breathing cycle using retrospective synchronisation [2]. Representative ventilation images, obtained during respiratory window of 150 ms, are shown in Figure 1. The Helium-3 signal evolution in the lungs was modelled by taking into account the gas exchange between the lungs and the reservoir, the RF depolarization, and the T_1 relaxation in the lungs as well as in the reservoir [3,4]. Experimental and simulated signal evolutions are shown in Figure 2.

Discussion and conclusion:

In this study, the feasibility of free-breathing Helium-3 ventilation imaging was demonstrated on rabbit lungs. The method gives access to the entire breathing cycle at tidal volume. It takes advantage of the reduced RF magnetization sampling and k-space sampling properties of the spiral imaging sequence. Upcoming studies will test this spiral imaging protocol on non-cooperative patients.

References:

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Acknowledgments:

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