High-quality Ventilation Imaging of the Human Lung using 100 ml of Helium-3

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Introduction: The recent steep decline in the supply of helium-3 (He3), and the associated substantial increase in price, has provided new impetus for minimizing the volume (dose) of He3 required for hyperpolarized-gas MR imaging of the lung. Two straightforward ways to decrease dose include increasing gas polarization and optimizing the SNR efficiency of the imaging method. Recently, a high-capacity, spin-exchange optical-pumping "hybrid" polarization system was reported, which uses two alkali metals to routinely achieve gas polarizations of approximately 60% [1]. In addition, several investigators have described the use of balanced steady-state free-precession pulse sequences (e.g., TrueFISP), as an alternative to the commonly-used spoiled gradient-echo (GRE) methods, for providing a substantial increase in signal-to-noise ratio (SNR) compared to GRE techniques [2,3]. The purpose of this work was to perform a preliminary assessment of the quality of He3 ventilation MR images that can be obtained with a He3 dose of only 100 ml by combining increased polarization with a TrueFISP acquisition.

Methods: Our standard approach for performing ventilation (spin-density) imaging in adults uses 300-400 ml of hyperpolarized He3 polarized to 35-40%, a 2D spoiled-GRE pulse sequence, and a voxel volume of approximately 3 x 3 x 10 mm. In roughly 1000 studies, this approach has yielded an SNR which is at least 20, and typically higher. In the current study, we sought to reduce the required volume of He3 by several fold (to 100 ml) by using higher polarization and a pulse sequence (TrueFISP) that can yield increased SNR compared to a standard spoiled-GRE acquisition.

Imaging was performed at 1.5T (Avanto, Siemens Medical Solutions, Malvern, PA) using a flexible chest RF coil (Clinical MR Solutions, Brookfield, WI). Helium-3 gas was polarized by collisional spin exchange with an optically-pumped rubidium/potassium vapor using a custom-built system; technical details are provided in ref. [1]. Measured polarizations ranged between 55 and 62%. Coronal ventilation images were acquired in five healthy subjects using a two-dimensional TrueFISP pulse sequence and the following parameters: TR/TE 2.6/1.1 ms; flip angle 25°; voxel size 3.3 x 3.3 x 10 mm. Each subject inhaled a gas mixture containing 100 ml of hyperpolarized He3 and medical grade nitrogen for a total volume equal to approximately one-third of the subject's forced vital capacity. All experiments were performed under a Physician's IND for imaging with hyperpolarized He3 using a protocol approved by our institutional review board. Informed consent was obtained in all cases. For each image set, the SNR for the central slice containing the carina was calculated.

Results: SNR sufficient to provide good depiction of the inhaled gas distribution was obtained in all subjects. The central-slice SNR values for the five subjects were: 28, 32, 43, 43 and 43. Representative images from the subjects having the lowest (Fig. 1a) and highest (Fig. 1b) central-slice SNR values are shown below. Gradual variations in signal intensity across the lung volume are attributed to B1 inhomogeneity of the close-fitting transmit/receive RF coil.

Conclusions: The combination of ~60% polarization and the SNR efficiency of TrueFISP imaging permit high-quality He3 ventilation MR images of the adult lung to be obtained using only 100 ml of hyperpolarized He3.

References: **1.** Mooney KE et al. ISMRM 2009; 2166. **2.** Mugler JP 3rd et al. ISMRM 2002; 2019. **3.** Wild JM et al. J Magn Reson 2006;183:13-24.

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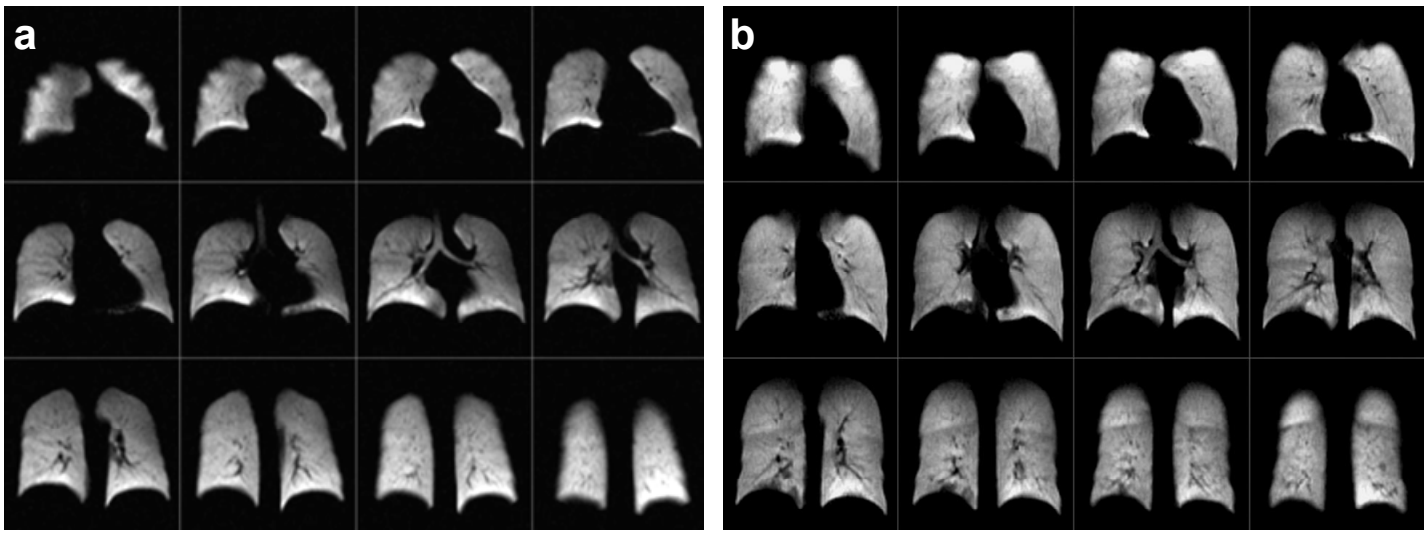

Fig. 1. Coronal He3 2D-TrueFISP images from (**a**) the subject with the lowest central-slice SNR and (**b**) the subject with the highest central-slice SNR.