A Comparison of Hyperpolarized Helium-3 and Xenon-129 MR Ventilation Imaging in Cystic Fibrosis

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Background: Hyperpolarized helium-3 (HHe) is a gaseous contrast agent for lung MRI that provides images of the inhaled HHe distribution with high temporal and spatial resolution. Commonly termed "ventilation imaging," this technique has shown areas of reduced or absent HHe signal, so-called ventilation defects, in patients with obstructive lung diseases such as cystic fibrosis (CF), asthma, and COPD (1-3). During a period of several years since 2001, consumption of helium-3 by national defense related applications increased tremendously, far outstripping the available supply and resulting in reduced helium-3 availability and substantially increased cost. Fortunately, recent developments in xenon-129 polarization technology have enabled routine human-lung imaging with hyperpolarized xenon-129 (HXe) (4). An unanswered question is whether the distribution within the lung of inhaled xenon-129, which has an atomic weight 43 times that of helium-3, is different from that for helium-3.

Purpose: To assess the concordance of HHe and HXe MR ventilation imaging in subjects with CF.

Methods and Materials: Six subjects with CF (age mean 28 yrs, range 19-39 yrs; FEV_1 mean 72%pred, range 49-102%pred) each underwent spirometry and both HHe and HXe ventilation imaging on the same day (Table 1). Helium-3 and xenon-129 were polarized using prototype commercial systems (Helium: Magnetic Imaging Technologies Inc., Durham, NC; Xenon: Xemed, Durham, NH), and polarizations of 20%-40% were achieved. For each HHe MR acquisition, a 1- or 2-L tedlar plastic bag (Jensen Inert Products, Coral Springs, FL) was filled with between 300 and 600 mL of HHe and enough nitrogen to total approximately 1/3 of the subjects FVC. For each HXe acquisition, a 1-L tedlar bag was filled with between 500 and 700 mL of HXe, and two bags were connected via a Y-connector: one containing the HXe and the other containing medical grade oxygen and room air. The total volume of these two bags was approximately 1/3 of the subjects FVC and the oxygen concentration of the total mixture was ~21%. All imaging was performed in a breath hold following inhalation of the HHE or HXe gas mixture. A variety of 2D ventilation acquisition methods were assessed at 1.5T (Avanto, Siemens) as shown in Figure 1 (in one subject, one acquisition, not shown, was perform at 3T [Trio, Siemens]). Either a flexible (Clinical MR Solutions) or rigid (Rapid Biomedical) chest RF coil was used for HHe, and a rigid (custom built) chest RF coil was used for HXe. Acquisition parameters were: GRE: TR/TE/FA 6.1/2.3/10° (HHe) or 9.4/3.7/10° (HXe); balanced SSFP (TrueFISP): TR/TE/FA 2.6/1.1/25° (HHe) or 4.6/2.0/40° (HXe); and spiral: TR/TE/FA 7.7/0.8/20° (HHe) or 10.9/1.0/20° (HXe). The spatial resolution was 4x4x15 mm for all methods.

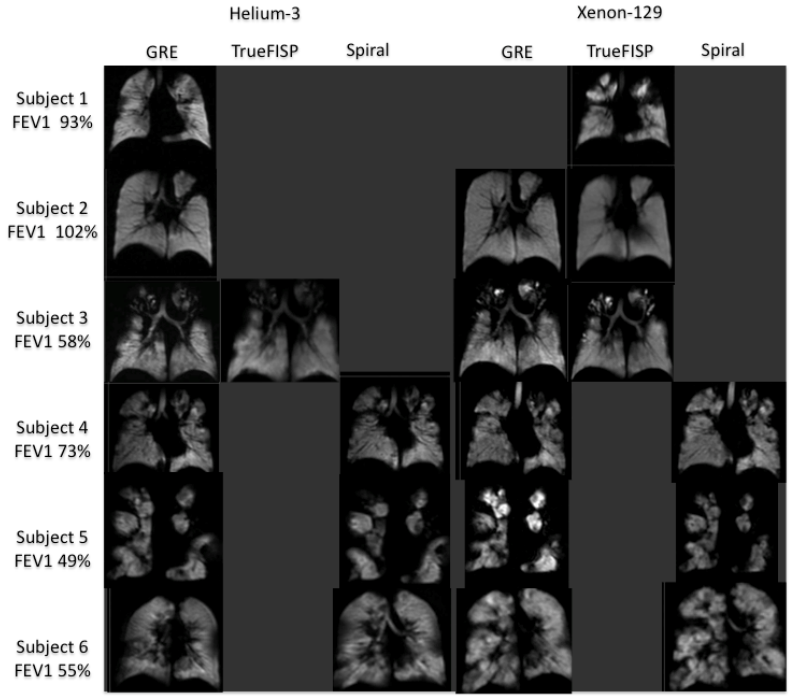

Figure 1: Coronal HHe and HXe MR images from 6 subjects with CF. Most subjects have ventilation defect in similar locations on both HHe and HXe MRI; however, there are some differences in the appearance of both the defects and the more normally ventilated lung in some subjects. In particular, Subjects 1 and 6 have more conspicuous and larger defects on HXe. Subjects 2 and 4 have nearly identical defects on HHe and HXe. Subjects 3 and 5 have similar appearing defects but there are focal areas of hyper-intense signal with HXe not as apparent with HHe.

Results and Discussion: All subjects had ventilation defects on both HHe and HXe, even those with normal spirometry. In some subjects the appearance of the ventilation defects was nearly identical with HHe and HXe (e.g., Subjects 2 and 4). In others, defects were present with both gases but were better defined, more numerous, and/or larger with HXe (e.g., Subjects 1 and 6). We speculate that the higher diffusivity of helium-3 allows more helium than xenon to enter regions of partial airflow obstruction, while areas with complete airflow obstruction would be expected to appear the same. Subjects 3 and 5 had focal areas of hyperintense signal with HXe that were not present with HHe. Interestingly, such hyperintensities were present on GRE and TrueFISP imaging but not spiral imaging, perhaps related to the very short acquisition time for the spiral method. In well-ventilated regions, TrueFISP images had a smoother appearance (Subjects 2 and 3) which may be due to reduced susceptibility effects adjacent to blood vessels. In general, GRE and spiral images appeared very similar to one another.

Conclusion: The appearance of ventilation defects with HHe and HXe was nearly identical in some CF subjects while in other the defects were more conspicuous, larger, and/or more numerous with HXe, which suggests HXe may be more sensitive to areas of partial airflow obstruction.

Acknowledgements: This study was funded by Vertex Pharmaceuticals Inc. General research support was provided by Siemens Healthcare.

References: 1. Kauczor HU, et al, JMRI. 1997;7(3):538-43 2. Donnelly LF, et al, Radiology. 1999;212(3):885-9 3. Atles TA, et al, JMRI. 2001;13(3):378-84 4. Hersman FW, el al, Acad Radiol. 2008;15(6):683-92