Signal Distribution in Dissolved 129Xe MR Images of Healthy Subjects and Subjects with Chronic Obstructive Pulmonary Disease

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Introduction: When taken up by the pulmonary tissues, dissolved hyperpolarized (HP) ^{129}Xe is readily distinguished from gaseous ^{129}Xe in the airways by a greater than 200 ppm downfield chemical shift [1]. Moreover, it was recently demonstrated that single-breath MR images of human lungs can be acquired from dissolved ^{129}Xe [2,3]. Because the SNR of these images depends on gas uptake, dissolved ^{129}Xe may provide a unique method of visualizing the distribution of gas exchange in both normal and diseased lungs. Before dissolved ^{129}Xe MRI can be used diagnostically, however, it is necessary to understand the factors that determine the signal intensity distribution in these images. To this end, we investigate the spatial distribution of dissolved ^{129}Xe in healthy subjects and subjects with chronic obstructive pulmonary disease (COPD).

Methods: Studies were performed during a GE Healthcare sponsored, Phase I clinical trial for ^{129}Xe MRI. Work was conducted under a GE Healthcare IND and approved by our IRB. Subjects consisted of 6 individuals diagnosed with chronic obstructive pulmonary disease (COPD) and 6 age matched controls (AMC). Images were obtained at 1.5 T using a GE EXCITE 14M5 MR scanner and a 17.66-MHz quadrature vest-coil (Clinical MR Solutions, Brookfield, WI). Subjects received 1-L doses of isotopically enriched Xe (83% 129Xe) polarized to 6-9% using 2 prototype GE polarizers. All images were acquired with subjects in the supine position during a 16-s breath hold period using a 3D radial sequence (views =3751, matrix=32×32×32, FOV= 40×40×48 cm^3, TR/TE=4.2/0.9 ms, BW=15.6 kHz, α=8°) that selectively excited the dissolved ^{129}Xe resonance. Ventilation images [matrix=64x64, FOV=40×(28-40) cm^2, slice thickness=15 mm, TR/TE=7.9/1.9 ms, BW=8 kHz, α=5-7°] were acquired using a slice selective SPGRE sequence. Image analysis was performed using routines written in MATLAB.

Results and Discussion: As was reported previously [2,3], healthy subjects displayed gravity dependent SNR gradients, with signal increasing in the anterior (gravitationally nondependent) to posterior (dependent) direction. This trend results from underlying gravity-dependent gradients in ventilation [2,4], with additional contributions arising from gradients in tissue density [5,6] and alveolar surface-to-volume ratio [7,8]. However, the trend is reversed in the most dependent portions of the lungs, likely due to reduced ventilation in the lung periphery [9]. Substantial isogravitational SNR heterogeneity, as measured by the coefficient of variation (CV) of a given slice, is also observed in the dissolved ^{129}Xe images of healthy subjects. This heterogeneity can be attributed to a combination of poor peripheral ventilation [9] and isogravitational heterogeneity in pulmonary perfusion [10]. However, the slice-by-slice CV of SNR also demonstrates a degree of directionality, with a maximum being observed in the central portions of the lungs. Additionally, significant differences in dissolved ^{129}Xe SNR and CV are observed between the right and left lungs. Similar left-right differences are not observed in corresponding ventilation images, suggesting that gravitational tissue compression by the heart [11] plays a role in determining the distribution of the dissolved ^{129}Xe signal. However, the gravitational and left-right patterns observed in AMCs are reduced or absent in individuals with COPD, indicating disease-associated changes in ventilation, perfusion, and tissue density dominate the dissolved ^{129}Xe images of subjects with COPD.

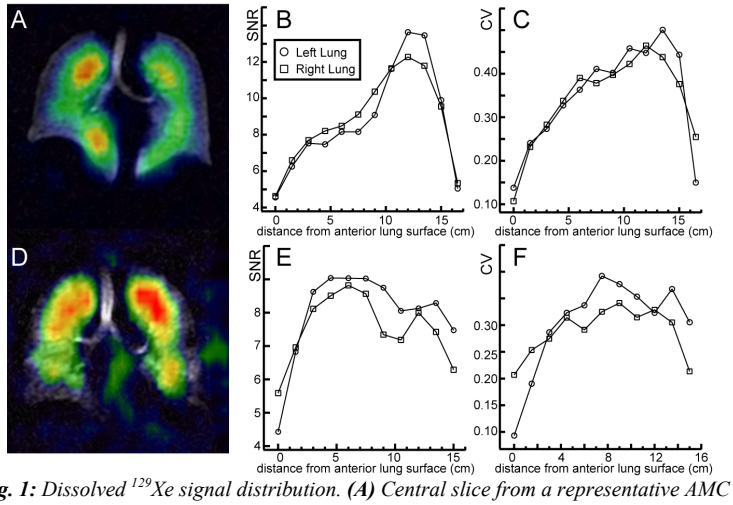

Fig. 1: *Dissolved ^{129}Xe signal distribution.* ***(A)*** *Central slice from a representative AMC subject. The dissolved image (color) is overlaid on the grayscale ventilation image.* ***(B)*** *Slice-by-slice SNR distribution from the subject in A.* ***(C)*** *Corresponding slice-by-slice CV distribution.* ***(D)*** *Central slice from a representative subjects with COPD.* ***(E)*** *SNR distribution from the subject in D.* ***(F)*** *Corresponding CV distribution.*

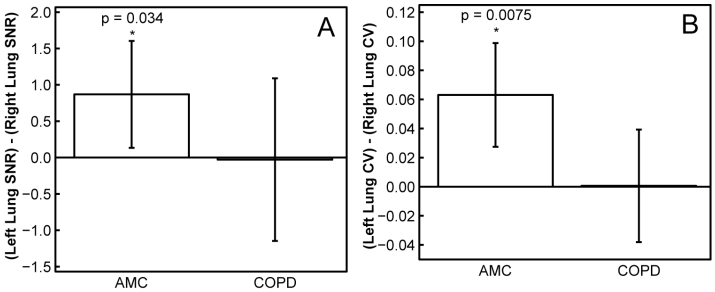

Fig. 2: *Average differences between the left and right lungs for both subject groups.* ***(A)*** *Left-right differences in SNR.* ***(B)*** *Left-right differences in SNR heterogeneity (CV).*

Conclusions: Dissolved ^{129}Xe images can be obtained from both healthy individuals and subjects with COPD. Images from healthy individuals display gravitational and isogravitational heterogeneity that likely reflects heterogeneity in the underlying pulmonary physiology. Differences in signal intensity and heterogeneity are also observed between the right and left lungs, which may be due to tissue compression by the heart. These patterns are reduced in subjects with COPD suggesting the dissolved ^{129}Xe is sensitive to disease-associated physiological changes.

References: **[1]** JP Mugler, et al. *MRM* **1997**, 37, 809-815. **[2]** JP Mugler, et al. *Proc 18th Annual ISMRM* **2010**. **[3]** ZI Cleveland, et al. *PLoS One* **2010**, 5, e12192. **[4]** DS Gierada, et al. *NMR Biomed* **2000** 13, 176-181. **[5]** SR Hopkins, et al. *J Appl Physiol* **2007**, 103, 240-248. **[6]** LH Brudin, et al. *J Appl Physiol* **1987**, 63, 1324-1334. **[7]** S Fichele, et al. *JMRI* **2004,** 20, 331-335. **[8]** SS Kaushik, et al., MRM **2010** accepted. **[9]** AJ Deninger, et al. *MRM* **2002**, 48, 223-232. **[10]** M Mure, et al. *J Appl Physiol* **2000** 88, 1076-1083. **[11]** RK Albert and RD Hubmayr, *Am J Resp Crit Care Med* **2000** 161, 1660-1665.

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