Mapping Human Pulmonary Oxygen Partial Pressure in Supine and Vertical Orientations: Initial Results

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Introduction

Regional heterogeneity of pulmonary ventilation and pulmonary perfusion is well-known to be influenced by gravity [1,2], but is also affected by the lung parenchyma and surrounding organs, leading to controversy over which effect is more physiologically relevant [3,4]. Of particular interest is the change in gas exchange dynamics when a subject is moved from a supine to an upright position. A key measure of the effectiveness of ventilation and pulmonary perfusion is the alveolar partial pressure of oxygen, p_AO_2. MRI using hyperpolarized ^{3}He has, in recent times, provided the first regionally-selective measure of p_AO_2 [5-6], which has been correlated with the traditional ventilation-to-perfusion ratio, *V/Q* [5]. However, current MRI systems restrict subjects to horizontal positions only. We have designed and built an open-access human MRI system to permit study of pulmonary function with subjects in a variety of postures [7]. Using this system, we have made initial measurements of human p_AO_2 in subjects in both vertical and supine positions.

Methods

The open-access human MRI system was optimized to operate at B_0 = 6.5 mT (65 G) applied field, allowing ^{3}He MRI at 210 kHz. Subjects at FRC inhaled ~ 500 cm^3 of polarized ^{3}He gas from a Tedlar bag, which was filled directly from a home-built spin-exchange polarizer. We acquired 2D gradient-recalled-echo images, without slice selection, over a 50 cm FOV, data size 128 × 32, TR/TE = 64/10 ms, NEX = 1, FA = 3º, in ~ 2 seconds. Multiple 2D images were acquired with 5-second inter-image delays during a single breath-hold for p_AO_2 calculation from the ^{3}He MRI signal decay. Excitation flip angles were calibrated precisely beforehand using phantoms as the subject loading of the RF coil at 210 kHz was minimal and reproducible. All protocols were approved by the Partners Human Research Committee at Brigham & Women's Hospital, under an inter-institutional IRB agreement with Harvard University.

Results

Example p_AO_2 maps from the human lung, acquired while a subject was lying supine and sitting vertically, are shown in Figure 1.

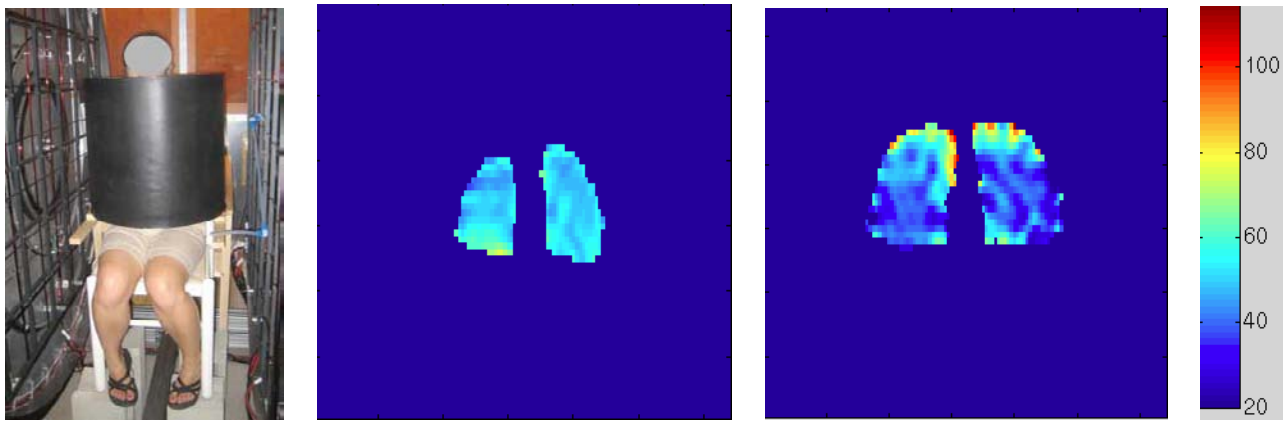

Figure 1: Left) Photograph of subject sitting vertically in the open-access MRI system. The chair is replaced by a support bed and the RF coil rotated 90º for supine imaging. Center) Calculated p_AO_2 map obtained from MR signal decay in 5 successive images, acquired while the subject was supine. Right) Calculated p_AO_2 map obtained from MR signal decay in 3 successive images, acquired while the subject was vertical. The color bar indicates the value of p_AO_2 in each pixel in both images, given in units of torr.

Discussion

The image at right represents the first time human p_AO_2 has been imaged in an upright human subject. A significant gradient in p_AO_2 is seen in the top third of the lung, consistent with the "zones of the lung" description based on theoretical and invasive studies by West et al. [8]. Our imager also permits, for the first time, a non-invasive, direct comparison of p_AO_2 distribution in the same subject with the subject in vertical and horizontal orientations. As expected, the p_AO_2 map obtained when the subject is supine is very uniform, in agreement with trends seen previously in clinical MR scanners [6]. The actual values of p_AO_2 obtained, ~ 50 – 60 torr when horizontal and ~ 40 – 80 torr when vertical are somewhat lower than physiologically normal values, most likely due to the subject inhaling only 500 cm^3 of ^{3}He from FRC, and the long imaging time required for these measurements in the open-access scanner.

Acknowledgements

We acknowledge support from NASA grant NAG9-1489, the Smithsonian Institution and Harvard University.

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