Human lung imaging in supine versus upright positions with a 6.5 mT open-access 3He MRI system: 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. Pulmonary function tests performed on upright individuals measure global parameters sampled at the mouth only. MRI [5] and PET [6] imaging can resolve regional dynamics such as *V*/*Q*, but current imaging systems restrict subjects to horizontal positions only. We recently demonstrated *in vivo* ^{3}He MR imaging of human lungs in the supine and upright positions in a prototype system at ~ 4 mT [7]. Building on those results, we have designed and built an optimized open-access human MRI system that employs a very low applied magnetic field, with the specific aim of studying pulmonary function with subjects in a variety of postures.

Methods

The second-generation 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 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 employed 2D and 3D gradient-recalled echo sequences. 2D images were acquired without slice selection over a 50 cm FOV, data size 128 × 64, TR/TE = 86/10 ms, NEX = 1, FA = 5º, in ~ 5 seconds. Multiple 2D images were acquired during a breath-hold for pO_2 calculation via the standard method [5]. 3D images were acquired over a 50 × 50 × 12 cm FOV, data size 128 × 64 × 6, TR/TE = 86/10 ms, NEX = 1, FA = 4º, in ~ 35 seconds. All protocols were approved by the Partners Human Research Committee at Brigham and Women's Hospital, under an inter-institutional IRB agreement with Harvard University.

Results

Example 2D and 3D lung image acquired while the subject was sitting vertical and lying supine are shown in Figure 1.

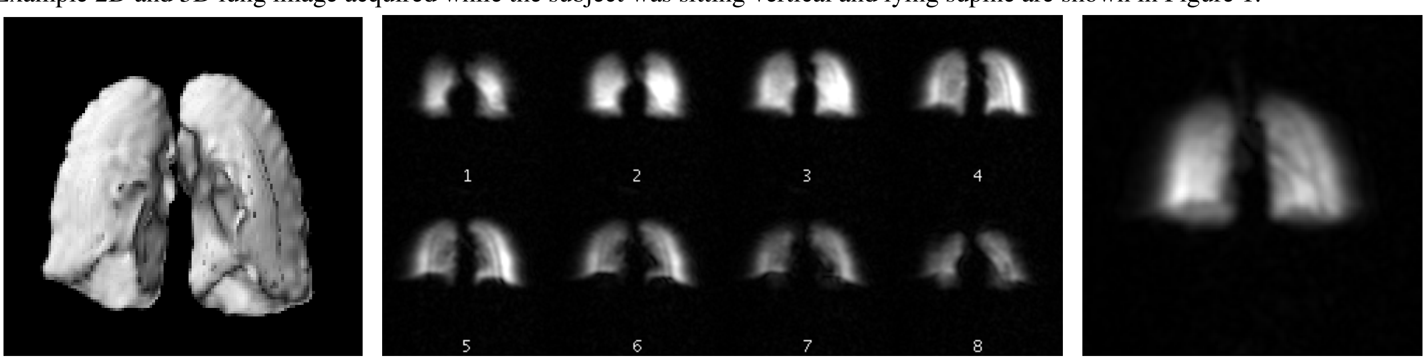

Figure 1: Left) 3D volume-rendered image of human lungs obtained while the subject is supine. Center) ~ 1.5 cm thick horizontal slices from the 3D dataset are plotted from posterior to anterior. Right) 2D projection image acquired while the subject was vertical.

Discussion

The 3D imaging technique provides a clear representation of the lungs, despite the very low applied magnetic field. After rendering, the pleural boundaries are clear and the cardiac cavity is clearly visible. In the 2D slices, the effect of the diaphragm is seen on the lower portion of the lungs. When the subject is sitting vertically, the characteristic curvature from the diaphragm at the bottom of the lungs is no long visible, and the lungs are distended slightly. The optimized imaging system has realized significant improvements in B_0 homogeneity and environmental noise suppression over that obtained with the prototype open-access imager [7]. SNR is improved by over an order of magnitude, however despite B_0 homogeneity improvements, further improvements in this area will allow for clear definition of the pleural boundaries in 2D images. Nonetheless, we have demonstrated that hyperpolarized helium can be imaged at B_0 < 10 mT with SNR within an order of magnitude of that realized at 1.5 T as recently predicted [8]. The magnet design permits 2-dimensional rotation of subject, allowing posture-dependent imaging and functional studies such as pO_2 and ADC measurements to be performed with subjects in a variety of postures.

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