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Magnetic Resonance Imaging of the Human Lung using Hyperpolarized ^{3}He Gas

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Human lung MR (magentic resonance) imaging has been investigated with optically polarized (via electron-nucleus spin-exchange) noble gas using the 1.5 T GE Signa MRI system.

The magnetic resonance signal intensity of a given nuclear species depends on its total magnetization in the chosen sample volume element; that is, on the product of the nucleus density, the excess spin density per nucleus (polarization), and the volume of the element. In the magnetic field of 5 T, thermal equilibrium polarization at room temperature is $\sim 10^{-5}$, which is adequate for ^{1}H imaging in most of our human body. However, in lung system, the ^{1}H density is too small to give MR signal enough, which results in difficulty of human lung MRI.

Recently, the new method to increase the polarization of noble gas (^{3}He, ^{129}Xe) up to $\sim 10^5$ times of the value in thermal equilibrium has been developed, which gave us a possibility to get high-resolution lung MR image. Hyperpolarized noble gas which is made by collisional spin-exchange between optically pumped Rb vapor and ^{3}He/^{129}Xe nucleus, is inhaled in lung and the MRI scan is accomplished during breath-hold (10-20s) or inspiration.

We developed ^{3}He hyperpolarization apparatus (optical pumping system) with which we obtained large volume (1 liter) of ^{3}He gas with ~20% polarization. We have obtained coronal/axial slice-selection lung images, using hyperpolarized ^{3}He gas, with the quadrature flex coil on the MRI system. The results show that lung ventilation defects larger than 0.9*0.9*10 mm^3 can be detected, and that hyperpolarized ^{3}He lung MR imaging provides a detailed image of lung ventilation. Non-slice-selection dynamic images of the human airways have been achieved using a Fast Gradient-Echo pulse sequence during inhalation. The resulting images show differential contrast of both distal airways and lung periphery. With this technique, airways up to the 7th generation can be visualized, which may provide valuable information about the diagnosis and staging of pulmonary diseases involving construction of the airway.

Slice-selection dynamic imaging was performed in healthy volunteers to render the 3D

human lung airway tree. We obtained coronal slice-selective images during three inspirations, 400 ml HP ^{3}He gas diluted to 1 L with ^{4}He gas (Multi-Slab). The airways and the periphery of the images were segmented using 3D Slicer software, thereby rendering the 3D airway tree. This method can potentially be used to validate mathematical volumetric airway models or to study pulmonary diseases involving constriction of the airways, such as asthma.