Phase contrast imaging of flow dynamics in the lungs using Hyperpolarized Helium

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Introduction: The variation in geometry between normal or diseased conditions of the bronchial tree can affect distribution of the air flow in the lungs, which, in turn, influences the optimal distribution of inhaled aerosols within the lung anatomy. Imaging the flow dynamics of the inhaled gases within the lung structures provides the potential for achieving a better understanding of these distributions, as well as optimizing therapies using drug inhalation. Phase contrast MRI may be an attractive, non-invasive approach for imaging in-vivo gas flow. Recently, de Rochefort, et al [1] have successfully combined radial MRI with phase contrast approach to map gas velocities in the human trachea during a single inhalation. However, their study evaluated flow only in the upper airway (Venc: 3 m/s); and did not attempt to study the air flow in the smaller airways distal; due to their long acquisition time (12.3 s), it would have been difficult to generate reliable flow maps in the smaller airways. They also used a single surface coil element, thus not exploiting the potential use of phased array coils for achieving either high spatial or temporal resolution or faster scan times. We have developed a dual-echo SSFP approach combined with parallel imaging technique to achieve this goal and present some of our early results in this abstract.

Methods: A dual-echo SSFP sequence (Figure 1) was combined with TSENSE parallel imaging in order to acquire the phase contrast data. A bipolar gradient was implemented in the non-readout direction between the two echoes; hence while the second echo was flow-encoded, the first echo served as a reference echo. This sequence was implemented in an unsegmented manner, and a flyback gradient was applied between the two readouts to align the two echoes correctly. Studies were performed using parallel imaging rates 1 to 4 in the phase-encoding direction on a clinical whole-body 1.5T Siemens Avanto scanner using a 3×4×2 element phased-array coil built in-house (2). ^{3}He was polarized by spin exchange with an optically pumped rubidium vapor to the level of 35-45% using GE Healthcare helium polarizers. Helium diluted with N_2 to a net polarization level of 12% was transferred to 1 liter Tedlar plastic bags and delivered to healthy human subjects. Imaging was initiated during slow expiration and the volunteer was permitted to breathe freely during the scan. Relevant scan parameters were: TR: 6.78 ms, TE: echo1: 1.7ms, echo 2: 5.12ms, slice thickness 8mm. The imaging matrix was 64 × 64 pixels for a FOV of 350×350 mm^3 giving a spatial resolution of 5.5 × 5.5 mm^3, and a velocity encoding range (Venc) of 50 cm/s was used .

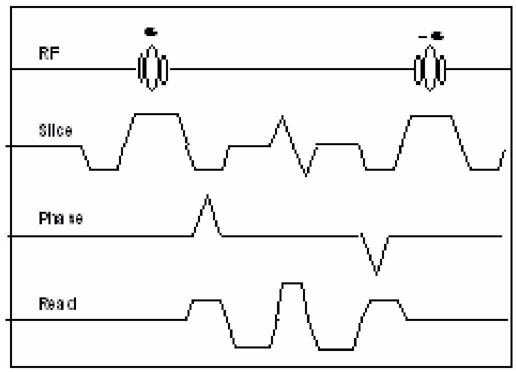

Figure 1. Dual-echo SSFP sequence for phase contrast lung function imaging using hyperpolarized helium

Results: Figure 2 shows the absolute and phase images for flow encoding in the left-right (L) and superior-inferior encoding (R) directions. With a parallel imaging rate of 4, we acquired each flow-encoded image in 110 ms, while the interleaving of the two encoding directions can be achieved in a temporal resolution of 220 ms. While the magnitude images show the effect of non-uniform coil intensities, the phase images appear to be less susceptible to this, though a more careful quantitative investigation is required.

Conclusion: We have developed a dual-echo SSFP approach, which in combination with parallel imaging, can be used to develop phase contrast function imaging of lungs using hyperpolarized helium. The use of high parallel imaging rates can permit us to trade the increased temporal resolution to improve spatial resolution of the images.

References: (1) de Rochefort L, et al. Magn Reson Med 2006;55(6):1318-25; (2) R. Lee et al. Magn Reson Med 2006;55(5):1132-41

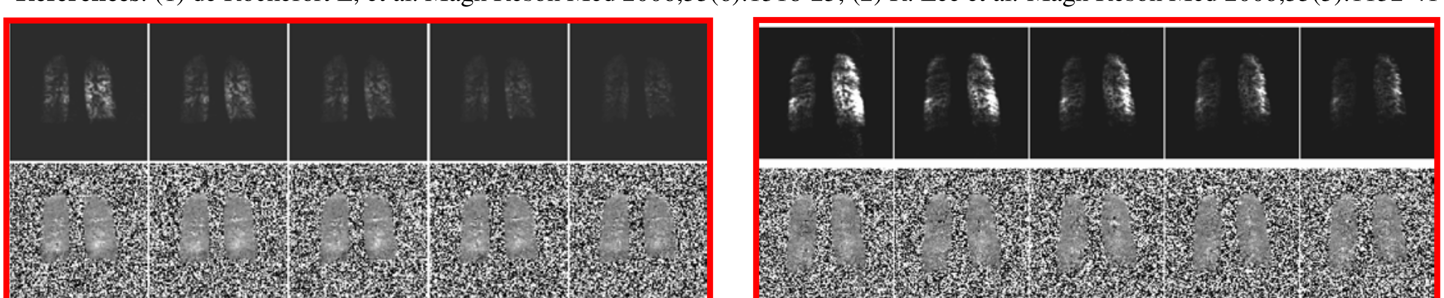

Figure 2. First five successive frames from phase contrast imaging in ^{3}He imaging. Top: Magnitude Images, Bottom: Phase Difference Images, Left: Left-Right flow encoding, Right: Superior-Inferior flow encoding.