High temporal resolution Hyperpolarized Helium imaging

V. M. Pai[1], I. E. Kamenetskiy[1], R. F. Lee[1], G. Johnson[1]
[1]Radiology, New York University, New York, NY, United States

Introduction: High temporal resolution dynamical imaging of the lungs using hyperpolarized helium can be used for diagnosis of many pulmonary diseases. Different techniques have been developed to achieve this. Fast EPI has been developed to achieve temporal resolution of 40 ms (1) for matrix size 32×64. A recently proposed projection reconstruction method (2) gives temporal resolution of 366 ms for matrix size 256×256. Interleaved spiral imaging can give temporal resolution of 3.4 ms for matrix size 128×128 using 24 interleaves and a sliding window technique for reconstruction (3). However, spiral imaging can be cumbersome to implement and the sliding window reconstruction leads to time averaging of the signal. Here we present an SSFP based multi-echo sequence that allows relatively high temporal resolution cine imaging of the lungs with hyperpolarized helium.

Methods: Our approach consists of using a multi-echo SSFP sequence in combination with parallel imaging. Also, in order to have high temporal resolution, each echo encodes a separate image, such that the center of k-space for each echo is traversed at a different instance in time. Figure 1 shows the travel in ky direction by each echo, while figure 2 shows the setup of the 3 echoes along with the large "blips" used in the phase encoding direction. Note that for this sequence, the zeroth and first moments are nulled in the slice select and readout direction, while only the zeroth moment is nulled in the phase encoding direction. In this reordering scheme, echo (and image) 1 encodes the center of k-space at 50 ms, echo 0 at 100 ms and echo 2 at 150 ms from the start of the acquisition. Studies were performed using SENSE rate of 4 on a clinical whole-body 1.5 T Siemens Avanto scanner using a 3×4×2 element coil constructed in-house. ^{3}He was polarized by spin exchange with an optically pumped rubidium vapor using a GE Healthcare helium polarizer. Helium polarized at 35-50% was diluted with N_2 to give a net polarization of 12%, and transferred to 1 liter Tedlar plastic bags and delivered to a healthy subject. Imaging was initiated during slow exhalation of the helium and the volunteer was permitted to breathe freely during the scan. The imaging matrix was 128 x 128 on a FOV of 300 x 300, yielding a spatial resolution of 2.35 mm x 2.35 mm, and a flip angle of 15 degrees was used for the RF pulses.

Results: Figure 3 shows the images acquired by each of the three echoes in the echo train. Note that there is minimal interference between the echoes, since the data are individually reconstructed. Figure 4 shows the images from the first 6 frames (3 echoes x 2) of a free-breathing scan of a normal volunteer inhaling hyperpolarized helium. Since SENSE rate 4 was used, each 3-echo set takes 170 ms to acquire, thus yielding a temporal resolution of 57 ms.

Conclusions: Utilizing a combination of a multi-echo SSFP sequence, a unique reordering scheme, and parallel reconstruction algorithms, we have been able to achieve true temporal resolution of 50 – 60 ms for a spatial resolution of 2.35 mm x 2.35 mm. This technique is easier to implement than spiral imaging.

References: (1) Saam et al. MRM. 1999; 42:507-514, (2) Holmes et al. Proc ISMRM, Miami, 2005, (3) Salerno et al. MRM 2001, 46:667-677.

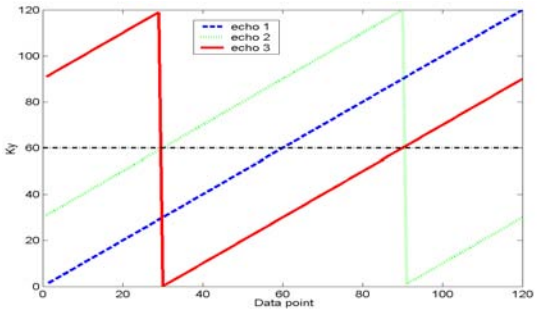

Figure 1.k-space travel by each echo of multi-echo sequence

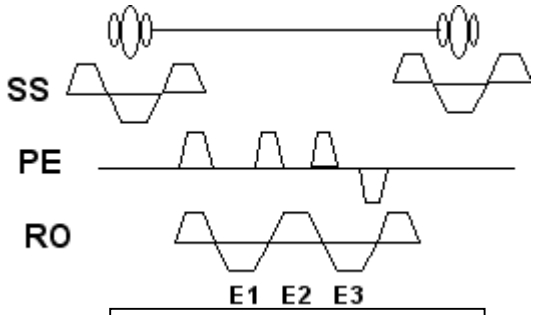

Figure 2.Pulse sequence per TR.

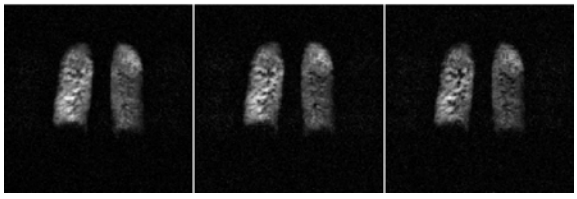

Figure 3. Representative images acquired for each echo. L: echo 1, C: echo 2, R: echo 3.

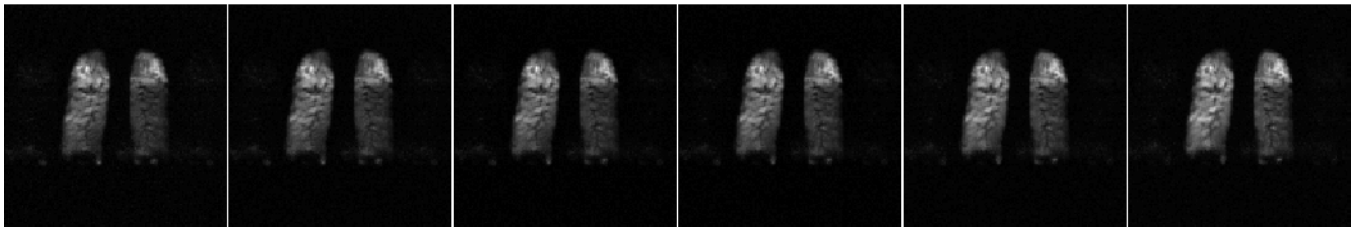

Figure 4. First six frames of the acquisition.