Parallel Imaging of Hyperpolarized Helium-3 with Simultaneous Slice Excitation

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Introduction Hyperpolarized (HP) gas imaging of the lungs is an ideal application for parallel imaging. This is due to the fact that there is limited scan time (breath-hold of 20 s) and limited non-renewable polarization. Reduced phase encode parallel imaging [1, 2] is demanding on hardware, in that it requires multiple receivers. Furthermore, these methods require prior characterisation of the sensitivity profile (reference scan), which requires further use of gas in a separate scan, or an increase in the breath-hold duration of a single scan. A different way of implementing parallel imaging without multiple receiver channels would be the use of simultaneously excited slice methods. In this work simultaneous parallel acquisition of HP ^{3}He images from multiple slices was demonstrated with a new sequence [3], which unaliases the images by selective slice rephasing of alternate echoes

Methods The sequence in Fig.1 [3] is a new method of simultaneously encoding *n* slices. A structured RF pulse was used to implement different phase profiles on each slice. Here slices are unaliased through selective rephasing and dephasing of the desired slice during frequency readout. This will require the use of an extra slice select gradient lobe and *n* echoes. Separation of the slices depends on size of rephasing lobe. The sequence (Fig.1) was implemented on a 1.5T whole body system equipped with a twin-saddle T-R coil. Spin exchange apparatus was used to polarize the ^{3}He gas to around 30%. All imaging was performed with 400 ml ^{3}He and 600 ml N_2 gas, which was delivered to a healthy subject with a Tedlar bag. Two acquisitions were made with read gradient strengths corresponding to two different bandwidths (61.25 and 31.25 kHz). In vivo imaging was then performed with slice thickness of 9.3 mm, 100 centric phase encodings, flip angle of 10˚ and FOV=38cm.

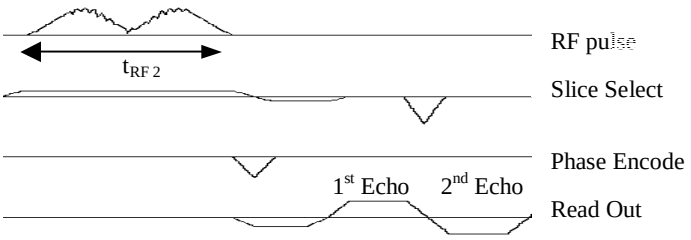


Fig 1: Sequence plot of the sequence.

Fig.2

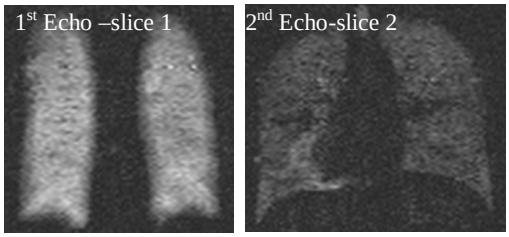
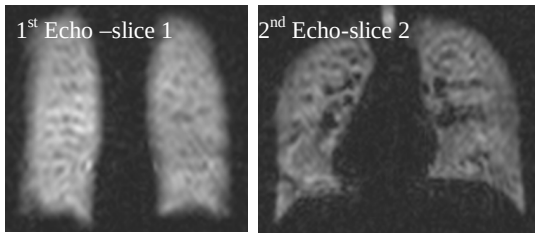


Fig.3



Results Figure 2 shows coronal lung images using a bandwidth of 61.25 kHz. There is a clear differences in SNR between the echoes. Figure 3 with a bandwidth of 31.25 kHz also shows coronal lung slices, less of a difference in SNR is apparent between slices. Note how the susceptibility dephasing around the vessels is more prominent in the 2nd echo due to the longer TE. The SNR values in both the Figure 3 images are higher than in Figure 2.

Discussion Parallel imaging using hyperpolarized ^{3}He gas has been demonstrated using a new sequence, which enables *n* slices to be encoded simultaneously. This study was done with a dual slice (*n*=2) implementation, there is room for improvement through use of higher orders of *n*. There are limitations of this technique; firstly loss in signal between the first and second echo due to T2* decay and diffusion dephasing effects due to the gradients. The second effect is typically quantified by the b-value of the readout gradient. The b-values of the first and second echo could be calculated from the read gradient waveform, and the attenuation of the signal will be given by exp(-bD), where D is the diffusion coefficient $D \approx 0.2 \times 10^{-4}$ m^2s^{-1} in vivo. By dividing the ratio of the attenuation at the first and second echo we can obtain the relative attenuation (RA) estimated as $(\exp^{-b2D} / \exp^{-b1D}) \times \exp^{(\Delta TE/T2^*est)}$. With TE 1.9 ms and $T_2^*{}_{est}$ estimated as 10 ms, we have predicted RA's of 64.5% for the high BW acquisition and 78% for the low BW acquisition. The SNR in the images was then investigated, and it was found that the mean SNR decreases significantly from the first to the second echo – mean RA observed 48% for the high BW acquisition and 72% for the low BW acquisition. The SNR with hyperpolarized ^{3}He is potentially very high, so a trade off of reduced SNR in the 2nd image for accelerated speed of imaging is tolerable. This sequence uses only one RF pulse for multi-slice images, therefore reduced imaging time will be achieved compared to standard single slice gradient echo sequences providing; $t_{RF\,2} < 2t_{RF\,1} + t_{PE}$. Whereby $t_{RF\,2}$ is the time for a complete dual slice RF pulse, $t_{RF\,1}$ is the time for a complete single slice RF pulse and t_{PE} the time for a complete phase encode with a conventional pulse sequence. In future work, other simultaneous slice excitation sequences [4] will be investigated with HP ^{3}He and this method will be combined with partial phase encode methods with multiple receivers, which could increase acceleration factors further still.

References

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