Fast Spin-Echo Sequence Optimization for Rapid T2-wieghted Mouse Imaging at High Field

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Synopsis

Magnetic resonance imaging (MRI) is emerging as a powerful tool for phenotyping mice in biological studies of disease progression, gene expression and development. Scan duration is a major problem in such studies. This problem is exacerbated at high field, where T1 relaxation times increase and converge. This frequently means T2-wieghted imaging offers superior endogenous contrast. However, the standard spin echo pulse sequence requires long repetition times (TR) to obtain pure T2-contrast in high resolution 3D data sets, resulting in scan times of tens of hours and prohibiting use in any high resolution *in vivo* imaging. The fast spin-echo (FSE or RARE) pulse sequence is an effective means of reducing scan time, but still suffers from the requirement for long TRs. The purpose of this abstract is to compare modifications to an FSE pulse sequence with the aim of maintaining a heavily T2-weighted image but with short TRs and reduced scan duration. Test scans of four sequences in phantoms of known composition and in a fixed mouse are evaluated and compared.

Materials and Methods

Three variants to the standard FSE were considered: application of a driven equilibrium pulse at the end of the echo train[1], reduction of the refocusing tip angle[2], and reduction of the excitation tip angle. Sequence verification was achieved by comparison of experimental signal-to-noise ratio data in a long-T2 phantom (1% agar, 0.5 mM $CuSO_4$, T1 = 1890 ± 40 ms, T2 = 137 ± 3 ms) with simulated signal results. All sequences were implemented using hard RF pulses. The reduced tip angle excitation sequence was also implemented with composite pulses in phantom experiments (such pulses had little or no effect in other sequences or in fixed mouse data).

Each sequence was then used to acquire a three-dimensional data set in a fixed mouse[3] without contrast agent (scan parameters TE/TR = 14/800 ms, TE_{eff} = 28ms, 8 echoes, 117 µm isotropic voxels, NEX = 2, scan time 2 hrs 50 min). An identical T2-weighted standard FSE reference scan with a long TR (TR = 3 s) was also obtained for comparison purposes (scan time 10 hrs 45 min). During the acquisition the read out direction was set along the length of the mouse and only phase encodes lying on Cartesian grid points within a cylinder were collected. This cylindrical k-space acquisition scheme reduces scan time by over 20%. All data was acquired on a 7.0 T scanner operated by a Varian INOVA console.

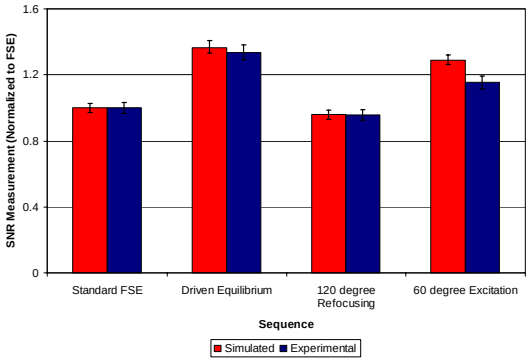
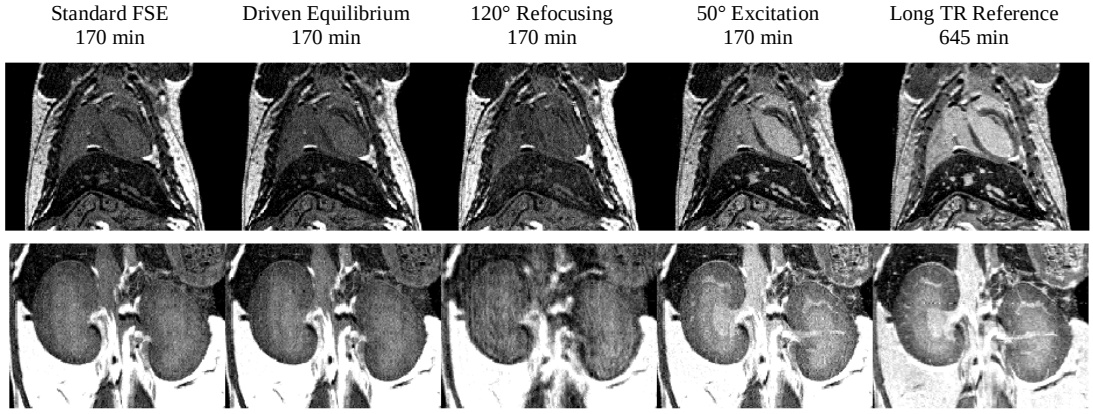


Figure 1: Experimental versus simulated SNR values for the phantom.

Results and Discussion

Figure 1 displays a bar graph of signal-to-noise ratios expected from simulations and experimentally determined from phantom images (normalized to the standard FSE). Experimental and simulated data agreed reasonably well. The reduced tip angle excitation sequence only produced 85% of the expected despite implementation of composite pulses; we believe this is due to the sequence's inherent sensitivity to B_0 and B_1 inhomogeneity effects as it, unlike the other sequences, requires maintenance of longitudinal magnetization over eight 180 degree pulses.

Figure 2 shows two slice portions from a 3D data set covering the whole mouse. The images were acquired in the same fixed mouse for each sequence variation. Overall average SNR in all images was approximately equivalent, with local increases in SNR in the reduced excitation sequence. The long TR reference scan had roughly twice the SNR of the short duration scans. The contrast from the reduced excitation scan was markedly improved and mimics that of the long TR reference scan. This is most noticeable in regions of vasculature and in the heart chamber, where the contrast-to-noise ratio increased three-fold. This contrast is obtained four times faster than the long TR reference FSE scan and forty times faster than a standard long TR 3D single spin echo sequence sampling k-space rectilinearly.



Conclusion

The modified excitation FSE sequence offers greatly improved T2-weighted contrast in rapidly acquired images (where TR<T1) in mice at 7.0 T without compromise in SNR. This shows promise for future acquisition of high-resolution *in vivo* data sets where scan duration is limited to the length of time a mouse can be anesthetized.

References

1. Maki J. H. *et al.* SNR Improvement in NMR Microscopy Using DEFT. JMR 1988. **80**:482-492., Busse R. F. *et al.* Interactive Fast Spin-Echo Imaging. MRM 2000. **44**:339-348.
2. Hennig J., Scheffler K. Easy Improvement of Signal-to-Noise in RARE-Sequences with Low Refocusing Flip Angles. MRM 2000. **44**:983-985.
3. Y.-Q. Zhou *et al.* Lab. Invest 2004. *In press*.