High field imaging of non-human primates: anatomical imaging and relaxation rates

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Introduction

Ultra-high magnetic field systems are seeing increased use in functional magnetic resonance image because of the intrinsic higher signal to noise and increased contrast to noise for susceptibility induced changes. To effectively use the increased signal in non-human primate imaging, the relaxation parameters for cerebral tissues and anatomical imaging protocols must be established. Pulse sequences suitable for anatomical image of non-human primates with implants are represented together with relaxation rates.

Methods

Rhesus macaques were imaged with a Varian 9.4T 31 cm system using a high duty cycle Magnex 305/210 gradient coil with maximum amplitude 20 mT m^{-1} and slew rate of 533 mT m^{-1} ms^{-1}. A circular 4.25 cm diameter surface coil centered on an implanted chamber over the visual cortex was used for excitation and receiving in all imaging.

Relaxation rates were measured in a single 1 mm thick 64 mm by 64 mm slice with 1 mm in-plane resolution. R_1 was measured with a Look-Locker sequence employing an 8 ms hyperbolic secant adiabatic inversion pulse, a sampling interval (τ) of 100 ms and a TR of 3.0 s. Four scans with nominal excitation angles of 5º, 10º, 20º, and 40º were used. For the N flip angles, the signal was fit to the Look-Locker equation[1] $S_n = k_1\left(1 - k_2 e^{-tR_{1eff,n}}\right)$. The resulting $R_{1eff,n}$ values were subsequently fit to[1] $\tau R_{1eff,n} = \tau R_1 - \ln\left(\cos\theta n\right)$ to obtain R_1 and flip angle maps. A spin echo sequence was used to measure R_2. Echo times of 15 ms and 25 ms were used with a repetition time of 3.0 s, where[1] $R_2 = \ln\left(S_1/S_2\right)/\left(TE_2 - TE_1\right)$.

Anatomical images were obtained with 3D gradient echo image and multi-slice fast spin echo. Both acquisitions cover a 64 mm by 64 mm by 32 mm FOV with the same 0.25 mm by 0.25 mm by 1 mm resolution. The 3D gradient echo sequence had a TE of 5 ms and TR of 25 ms with a nominal flip angle of 11º. The FSE used an 8 echo train with fourth effective echo for an effective TE of 46 ms and TR of 3.2 s. Gradient echo sequence used NEX = 2 compared to NEX = 4 for the FSE to ensure equal total imaging time of 6 min 50 s.

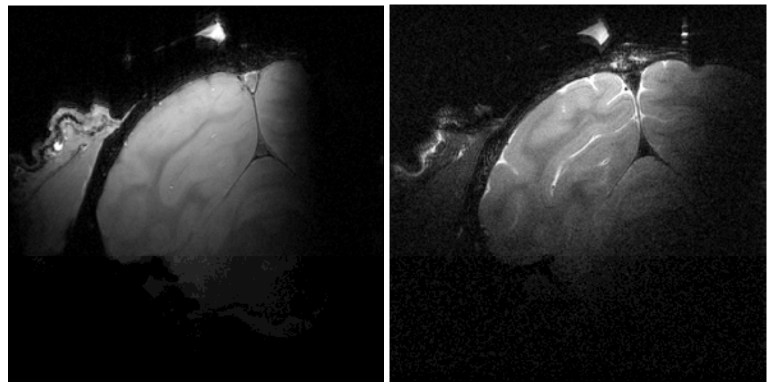

Figure 1 3D gradient echo (left) and fast spin echo (right) anatomical images of rhesus macaque brain at 9.4 T. Saline in implanted chamber can be seen above the head.

	Gray Matter	White Matter
T_1 (s)	1.64 ± 0.14	1.28 ± 0.09
T_2 (ms)	34.2 ± 3.0	31.7 ± 1.2

Table 1 Relaxation time constants for gray and white matter in a rhesus macaque at 9.4 T

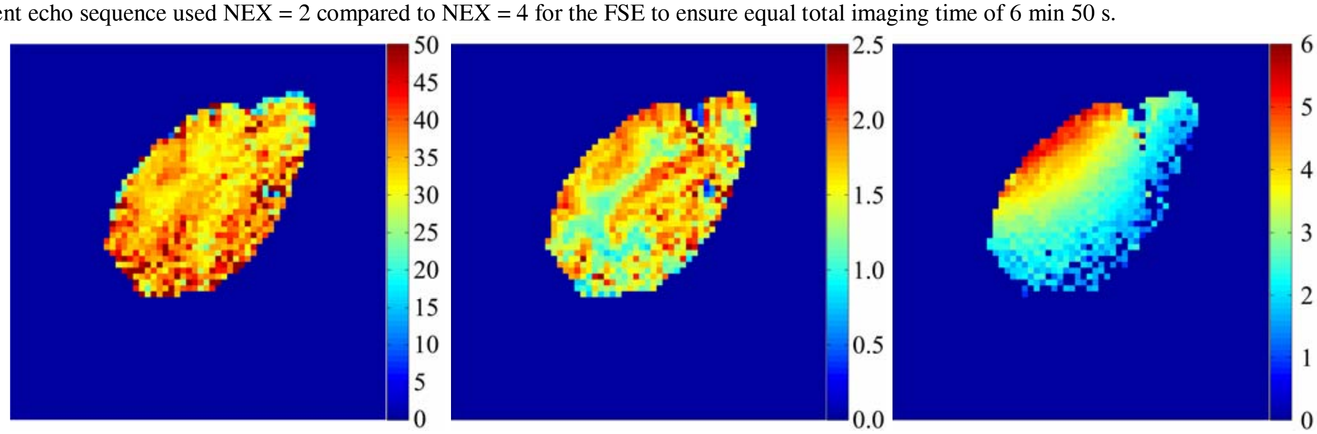

Figure 2 T_2 (ms), T_1 (s), and initial flip angle (degree) maps (left to right) for the corresponding slice to anatomical image in Figure 1.

Results

Figure 1 shows a representative slice of the gradient echo and FSE images. For equal total imaging time, the gradient echo sequence had SNR of 55 compared to 19 for the FSE sequence. Table 1 gives the relaxation time constants obtained for gray and white matter and Figure 2 show T_1, T_2, and initial flip angle maps.

Discussion

Due to the similar T_2 relaxation time constants of gray and white matter, the fast spin echo sequences provide better gray/white matter contrast, particularly in the higher flip region near the surface. Variable flip angle Look-Locker sequence provides a convenient method to obtain accurate flip angle calibration in addition to R_1 relaxation. Measurement of tissue relaxation rate will enable optimized imaging protocols for anatomical and functional imaging of rhesus macaques at 9.4 T.

References

1. Haacke, E. M. et al. 1999. Magnetic resonance imaging: physical principles and sequence design. Wiley, New York.