Comparison of Contrast-to-Noise Ratio for in vivo Mouse Brain Imaging at 3T and 7T under Nearly Identical Scanner Configurations

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Introduction

Since the introduction of MRI for in vivo applications, there has been a trend toward the use of increasing static magnetic field strength. This is motivated by the belief that high field strength will improve performance in MRI. For some types of contrast, most notably blood oxygenation (BOLD effect), that forms the basis of functional studies, enhancement with field strength has been demonstrated[1]. On theoretical grounds an improvement in signal-to-noise ratio (SNR) and tissue contrast-to-noise ratio (CNR) is expected from increased static field magnitude.

As higher fields, exceeding 3 Tesla, are employed, practical limitations can diminish CNR improvement. For example, T1 tends to lengthen as the field is increased creating a greater time burden on T2-weighted imaging. The difference in T1 between white and gray matter diminishes, requiring a lower noise floor to maintain the same CNR in brain images. Artifacts arising from magnetic susceptibility gradients or chemical shift effects become more troublesome as the static field is increased as well.

At least one study has measured an improvement in SNR with field strength in human brain[2]. This work compared performance at 4T and 7T, but used the same sequence parameters in two scanners of different manufacturers fitted with gradient coil sets of different sizes. The extent of the advantage gained in conventional image quality due solely to higher B0 field strength remains unclear.

SNR and CNR assessments of T1- and T2- weighted images in mouse brain obtained on 3T and 7T scanners with nearly identical gradient, RF coil, and software/protocol configurations are demonstrated. In this way, impact of field strength alone on image quality is explored.

Attribute	BioSpec 30/60	BioSpec 70/30
Field Strength	3T	7T
Gradient Configuration (20 cm)	B-GA 20 S2	B-GA 20 S2
Maximum Gradient Strength	42533 Hz/cm	81999 Hz/cm
Software	ParaVision v. 3.0.2	ParaVision v. 3.0.2
RF Receive Channel Noise Figure*	2.61 dB	1.65 dB

Table 1: System Attributes *averaged over a range of typical receiver gains

Methods

Two Bruker (Bruker BioSpin MRI Ettlingen, Germany) scanners were employed for this study; a BioSpec 30/60 and a BioSpec 70/30 with attributes listed in Table 1. The scanners were equipped with similar 20 cm gradient coils and the same Copley gradient amplifiers and operated under the same software. Maximum current limits were set differently for the two systems as indicated in Table 1. RF electronics on both scanners were at current revisions of the Bruker AVANCE™ platform. The RF receive channel noise figure was measured for each system and the difference accounted for in analysis of noise data.

A pair of identical, single-turn-solenoid RF coils were constructed for this comparison, each tuned and matched for its respective scanner environment. The coils measured 25 mm in diameter and 30 mm in length to closely accommodate a mouse head. Field uniformity was assessed with a homogeneous sample and found to have <5% variation over the region to be occupied by the mouse brain. Loaded with a mouse, the Q of the coils measured 306 and 212 for the 3T and the 7T version respectively.

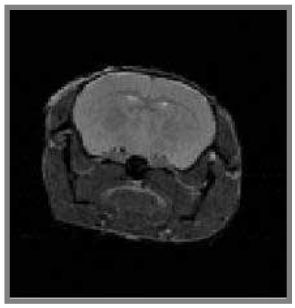

Fig. 1: 2D RARE @ 7T

To optimize contrast in the in vivo images, the characteristic T1 and T2 relaxation times in mouse brain at the two field strengths were measured. Methods for relaxometry were first tested using phantoms, sized for the RF coils, containing multiple compartments with different T1 or T2 characteristics. Phantom measurements of T1 vs. Gd and T2 vs. Agar agreed generally with those of earlier work with phantoms of these types[3]. Four female FVB/N mice (13-14 weeks old, avg. weight 21 gm) were scanned in vivo for this study. Relaxometry was first performed on a coronal slice of each mouse brain using protocols derived from the phantom results. Relaxation times at 3T and 7T for three anatomical regions are listed in Table 2.

Starting in the 3T scanner, each mouse was then imaged with T1- and T2-weighted 2D multi-slice RARE sequences (see Fig. 1). Images of the same mice were then made at both field strengths using identical scanning parameters as follows: geometric specifications (FOV: 19.2x19.2mm at 128x128 for a 150x150 micron resolution, slice: 0.5 mm thick, 8 slices 1 mm apart). For T2-weighted images, sequence specifications include: TR/effective TE=3000/40, 50 kHz BW, RARE factor=2, NEX=4, duration~21 min. T1 scans utilized: TR/TE=700/8.3, 50 kHz BW, RARE factor=1, NEX=8, duration ~12 min. Once the contrast-to-noise (CNR) was optimized in the 3T scanner, the same protocol was transferred to the 7T scanner to assess the effect of field strength alone on image quality. Subsequently, imaging parameters other than those specifying geometry were adjusted at 7T to optimize CNR for the higher field strength. The maximum influence of the field strength alone on CNR outcome could now be determined.

Anatomical Region	T1 (ms) (IR-RARE, TR/TE=10000/14, TI=70 to 8000 ms)		T2 (ms) (MSME TR/TE=1000/9, 64 echoes)	
	3T	7T	3T	7T
Hippocampus	1470	1740	74	55
Corpus Callosum	1280	1560	72	52
Cortex	1270	1830	72	50

Table 2: Mouse brain T1 & T2 Relaxation Times @ 3T & 7T

Results and Discussion

Many factors influence the image quality, characterized by CNR, attainable in MR. Provided with the singular opportunity to operate scanners at 3T and 7T with nearly all remaining parameters held constant, the isolated impact of field strength on small animal conventional imaging will be reported.

References

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