High-resolution and parallel imaging of rat brain using a dedicated 3-D orthogonal phased array coil at 3T

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Introduction

MR imaging of rat brain is useful for animal-model studies of brain diseases, injuries, function, and for stem cell research. While high field small-bore systems are often used, clinical MR scanners have the advantages of reduced field inhomogeneity and magnetic susceptibility artifacts [1], and the studies are also more translational for human applications. However, due to the small size of rat brain, image resolution much higher than those normally used on clinical scanners is needed. Human RF coils such as wrist coil have been used for rat brain MRI [2], but they have large volume and may not provide sufficient SNR to support the desired resolution. Custom phased array coils with elements along the coil circumference [3] may also be used for the rat brain, but they have poor signal homogeneity. Our imaging center had also used a commercial 4cm surface RF coil for rat brain MRI, but it had limited signal coverage, poor homogeneity and did not support parallel imaging. The objective of this study is to design and construct a phased array receive coil for rat brain MRI at 3T that provides high and uniform signal and is compatible with parallel imaging that saves scan time.

Methods

The study was conducted on a Siemens 3T scanner. The design of the rat brain coil was adapted from a coil for rhesus monkey brain [4]. It consisted of 2 volume saddle coil elements and a circular loop coil element that encircled the rat head for uniform signal. Its geometry resembled that of a rat head with a tip at the nose (Fig. 1), and this design minimized coil volume to optimize SNR. The coil was 6.3 cm in diameter at the base and 6.3 cm long (from base to tip). The anterior part of the saddle elements were made up of 3 parallel pieces of copper wire (gauge 20) to reduce electrical resistance. The posterior part of the saddle elements and the circular loop were made up of 6.25mm wide copper tape. The 3 elements in this coil were arranged orthogonally to each other, and coupling among them could in theory be reduced to zero [4]. During scans, the coil was oriented perpendicularly to the magnet with the circular loop element in the y-z plane. A 0.38% NaCl phantom was used to compare the performance of our coil with a 4cm Siemens surface coil. A deceased adult rat (280g) was imaged with various sequences. Since the rat head did not fit through the central opening of the 4cm coil, it was placed supine on top of the coil. Parallel imaging method GRAPPA with accelerated factor of 2 was also tested on our coil.

Results

Using the phantom, the ratios of the unloaded to loaded Q-factors for the 3 coil elements of our coil were measured to be 1.67, 1.58 and 2.0. Our coil provided much more homogeneous signal and 90% higher signal even at the location closest to the surface of the 4cm coil (Fig. 2). Rat brain image results are shown in figures 3-5.

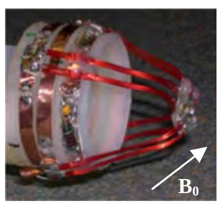

Fig. 1. Photo of the rat brain coil

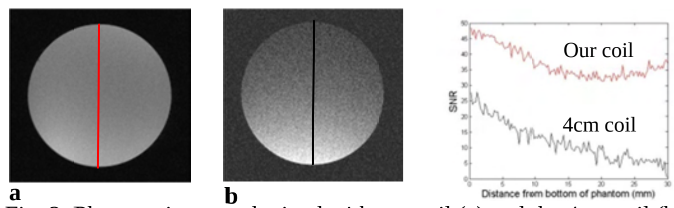

Fig. 2. Phantom images obtained with our coil (a) and the 4cm coil (b), and their SNR profiles along the indicated vertical line.

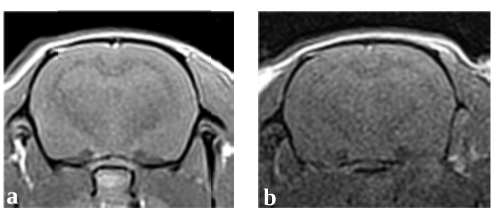

Fig. 3. T1W SE images obtained using (a) our coil and (b) 4cm surface coil with TR 600ms, TE 20ms, in-plane resolution 230x230µm and slice thickness 900µm. Our coil showed significantly better SNR and signal homogeneity.

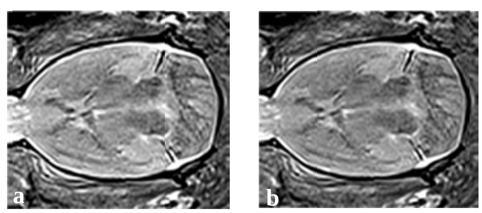

Fig. 4. T2W FSE image obtained (a) without and (b) with GRAPPA in 3:06mins and 1:42mins using TR 3s, TE 65ms, in-plane resolution 230x230µm and slice thickness 600µm.

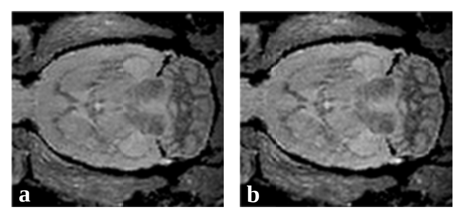

Fig. 5. T2*W 3D GRE imaging provided thin slice acquisition (a) without and (b) with GRAPPA in 25:38mins and 14:34mins using TR 400ms, TE 30ms, flip angle 25^0, 1 average and isotropic resolution of 270µm.

Discussion & Conclusion

We have developed a dedicated RF receive coil for high-resolution rat brain imaging. Compared with a commercial 4cm surface coil, it provides 1) much higher SNR, 2) more uniform signal and 3) a larger FOV coverage. In addition, our coil allows easy positioning of the rat head, while the 4cm coil requires precise positioning of the rat brain in the coil signal region. Our coil can also be used with parallel imaging to reduce scan time, and is able to produce high-quality GRAPPA images. This is particularly beneficial to T2*W 3D GRE imaging that generally requires long scan time, but can provide high-resolution thin slice image data that allows 3D reformation for studies such as iron-oxide labeled stem cell tracking. Our coil should be useful for MRI studies of rat brain.

References

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