Selection and Verification of a Throughput-Optimized Receive Array for Multiple-Mouse DCE-MRI

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Introduction

Compared to human imaging, small-animal MRI demands higher resolution and sensitivity to achieve image quality that is comparable to diagnostic clinical images. Resolution and SNR can be enhanced to the required level by appropriate protocol parameter selection, however, inherently at the expense of increasing imaging time (1). Unfortunately, many preclinical investigations require a large number of animals to be scanned for a desirable level of statistical power. This, along with the fact that MRI scanner access time is expensive, renders noninvasive investigation by MRI time- and cost-prohibitive for many biological investigations that could potentially benefit from MRI. Scanning multiple animals simultaneously within the same scanner has been successfully demonstrated to improve the throughput of small-animal MRI. The traditional method for multiple-mouse MRI has been to dedicate a single transceive volume coil to each of the animals being imaged (2), however, this technique places an absolute ceiling for imaging throughput improvement that is equal to the number of animals simultaneously scanned. Unfortunately, functional imaging protocols that are critical for therapy evaluation require substantial animal preparation, such as tail-vein catheterization in the case of dynamic contrast-enhanced (DCE-) MRI, making scanning a large number of animals at once cumbersome and inefficient. Dedication of a phased array coil, instead of a volume coil, to each of the animals being scanned was recently demonstrated to achieve throughput improvements greater than the number of animals simultaneously imaged though a combination of multiple-mouse and parallel imaging techniques (3). The purpose of this work was to determine and demonstrate the optimal coil configuration for maximizing the imaging throughput of a small-animal 2D multi-slice DCE-MRI study given 16 available receive channels.

Materials and Methods

A number of coil configurations were investigated for imaging from one to five mice simultaneously, some of which are shown in Figure 1. Configurations **I** through **V** utilized separate shielded transmit coils which limit the receive coil sensitivities to a single mouse and reduce interarray coupling, while configuration **VI** consists of a distributed array of coils within a single large transmit coil. Requirements for the coil configurations included: **A)** identical geometry of nearby coils surrounding each mouse to maintain consistent image quality between all mice. **B)** Up to 16 receive channels were available, but the number of transmit coils was not limited since power can be split between transmit coils. **C)** Only "unstacked" geometries were considered to ease animal access for physiological monitoring and setup. **D)** Coils must fit within the accessible space of a 30-cm bore MRI system. The Biot Savart law was used to estimate coil sensitivity profiles for each configuration in Matlab. Theoretical cylindrical phantoms were created to model each mouse and data was downsampled along the phase encode (L-R) direction to simulate parallel imaging. Sensitivity encoding (SENSE) *g*-factor maps were calculated for reduction factors, R = 1 to 10 to estimate non-uniform noise enhancement due to imaging acceleration (4). Imaging throughput was defined as $T = R \times N/F$, where R is the parallel imaging reduction factor, N is the number of simultaneously-scanned animals, and F is the matrix extension factor or the factor by which a single-animal field-of-view must be increased to cover all animals without acceleration (3). The 2D multi-slice DCE-MRI protocol under consideration consisted of the following individual scans: **1)** 2D positioning **2)** three-plane localizer **3)** high-resolution T_1-weighed coronal scout **4)** T_1-weighted precontrast axial **5)** T_2-weighted precontrast axial **6)** T_1 map **7)** dynamic spoiled gradient echo axial **8)** T_1-weighted postcontrast axial. Scans 1 and 7 are fixed-duration while the other scans can be accelerated with parallel imaging. A phased array based on the optimal configuration was fabricated and used for phantom imaging at 7T to verify acceptable image quality with the maximum tolerable acceleration per animal.

Results and Discussion

Figure 2 indicates the maximum resulting *g*-factor over all of the theoretical phantoms. Reduction factors that result in a *g*-factor < 2 for all mice were considered acceptable. The maximum tolerable reduction factor per animal or $R' = R/F$ for cases **I** to **VI** respectively were 4/1, 5/2, 7/3, 9/4, 9/5, and 8/5. Results of these reduction factors being compared to the single-coil, single-animal imaging times of the allowable accelerated scans indicate that the 29 minute unaccelerated scan time per mouse can be reduced to 14.8, 8.8, 6.1, 4.6, 4.1, and 4.4 minutes per mouse, for each of the configurations, respectively. The highest protocol throughput is achieved with configuration **V** (T_{avg} = 7.1) where five animals are each scanned with a three-element receive array coil and a shielded transmit-only birdcage coil. Individual coil, sum of squares combined, and GRAPPA-accelerated (5) phantom images from such a three-element array yield good image quality as shown in Figure 3.

References

1) McConville P *et al* Curr Opin Chem Biol, 9:413-420 (2005) **2)** Bock NA *et al* MRM, 49:158-167 (2003) **3)** Ramirez MS *et al* MRM (in press) **4)** Pruessmann KP *et al* MRM, 42:952-962 (1999) **5)** Griswold MA *et al* Magn Reson Med, 47:1202-1210 (2002)

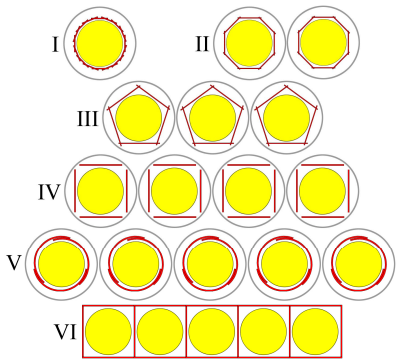

Figure 1

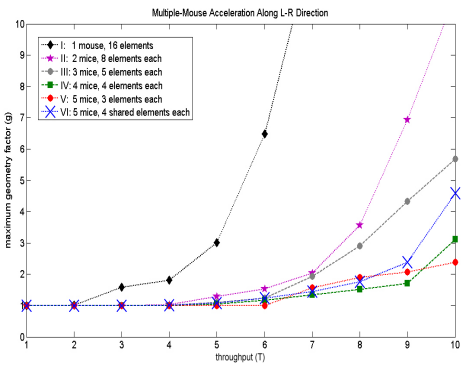

Figure 2

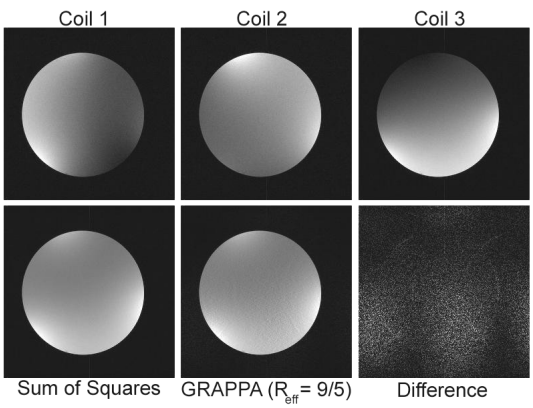

Figure 3