International Journal on Magnetic Particle Imaging
Vol 11, No 1, Suppl 1, Article ID 2503020, 3 Pages

Proceedings Article

Comparison of receive inserts for non-human primate fMPI in a human brain scanner

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Abstract

The receive coil geometry significantly influences MPI detection sensitivity, a primary distinguishing characteristic when competing with other tracer-based imaging methods. Here, we compare four gradiometric receive inserts for non-human primate functional MPI to identify a coil geometry that maximizes sensitivity while accommodating the primate head. A cylindrical coil with a diameter of 14 cm provided the highest sensitivity while fitting the macaque. Smaller cross-section gradiometers offered better rejection of noise originating from the shift coil amplifiers.

I. Introduction

Functional magnetic particle imaging (fMPI) measures local changes in cerebral blood volume (CBV) following neuroactivation. We are currently conducting non-human primate (NHP) fMPI studies on a human brain MPI scanner [1] as a step toward human neuroimaging applications with MPI. Designing an appropriate NHP receive coil represents a constrained optimization problem that aims to maximize sensitivity while fitting the NHP head. We previously introduced an NHP receive insert for our human-brain-sized MPI imager but neglected the anatomical constraints [2]. Here, we compare three additional receive inserts to maximize sensitivity under the constraint of spatial fit.

II. Methods and materials

Figure 1 shows the geometry specifications of the four gradiometric receive coil inserts. Coil #1 and Coil #2 are cylindrical coils, with Coil #2 having a 1.6-fold larger cross-sectional area. For NHPs with pronounced snouts, we designed Coil #3 and Coil #4 as ovoids, with Coil #4 tapering towards the gradiometer center to ensure a close fit around the brain.

We assessed the detection limit of the receive inserts using a 9-sample imaging dilution series of 70 nm Synomag-D (Lot: 18224104-01), ranging from 120 μg_{Fe} to 313 ng_{Fe}, each in a 20 µL dot phantom. For each mass, we acquired a 5 s 2D image and compared the signal intensity of a fixed pixel (determined by the peak in the highest concentration image) to the noise standard deviation of the empty bore image. The extrapolated linear fit of the

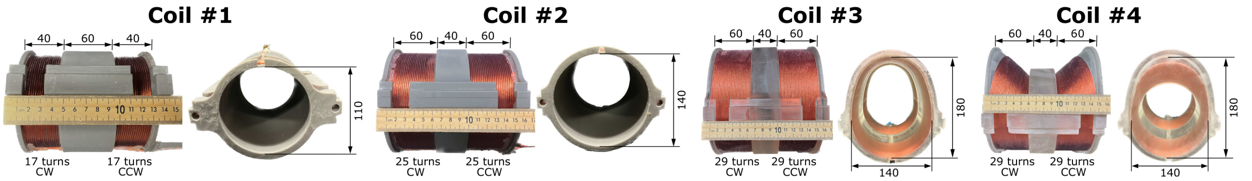

Figure 1: Front and side view photographs of the four receive coil inserts, with corresponding geometry specifications (in mm). The coil diameter increases from left to right, providing flexibility to fit varying NHP head sizes. Note: scales are inconsistent.

SNR-vs-mass line gives the SNR = 5 detection limit. Additionally, we imaged a G-phantom (Figure 2C) filled with 0.0313 $\mathrm{mg_{Fe}\,mL^{-1}}$ of Synomag-D, about 4x the concentration expected in the NHP brain gray matter (assuming a 10 $\mathrm{mg_{Fe}\,kg^{-1}}$ dose for an NHP with a blood volume of 70 $\mathrm{mLkg^{-1}}$). All images were reconstructed with an iterative forward-model algorithm and smoothed with a 6 mm FWHM Gaussian kernel.

III. Results and discussion

Figure 2A and 2B show the imaging dilution series results. The linear regression for SNR = 5 yields detection limits of 35 $\mathrm{ng_{Fe}}$, 65 $\mathrm{ng_{Fe}}$, 288 $\mathrm{ng_{Fe}}$, and 150 $\mathrm{ng_{Fe}}$ for Coil #1-4. Differences in image SNR are dominated by each coil's ability to reject noise from the system's shift coil amplifier [3]. This becomes evident when comparing image SNRs and peak-signal intensities of Coil #2-4 relative to Coil #1 (shift noise rejection of 100 %). For the 10 $\mathrm{\mu g_{Fe}}$ probe, the image SNRs of Coil #2-4 are 1.8x, 7.1x, and 4.0x lower compared to Coil #1 (image SNR of 1254), while their peak-signal intensities are only 1.6x, 3.5x, and 1.9x lower than that of Coil #1 (peak-signal of $7.8 \cdot 10^{-4}$). The larger cross-section coils have a notable SNR discrepancy to the peak-signal scaling factors, which can be attributed to their higher coupling to the shift coils' noise. Consequently, the smaller cross-section coils offer both a higher peak-signal intensity and a better rejection of the shift noise. However, since Coil #1 does not fit the NHP, Coil #2 is the preferred choice for fit with minimal SNR reduction.

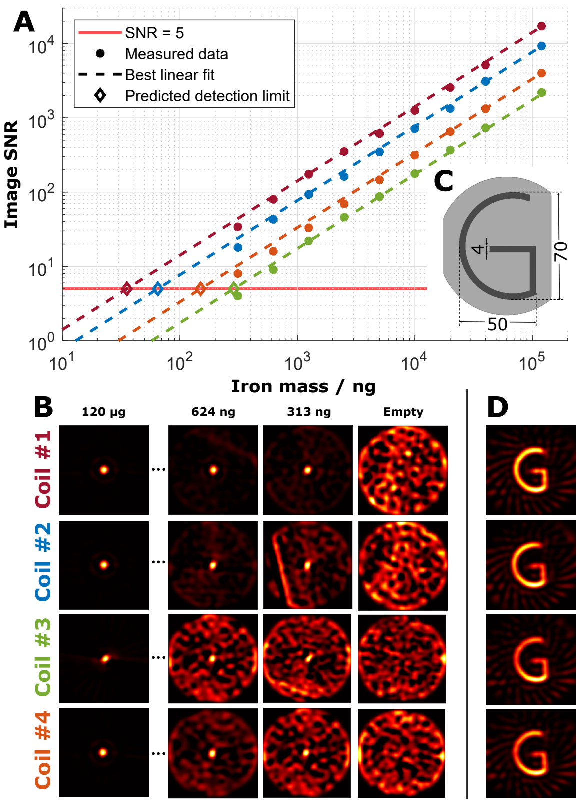

Figure 2: **A** Linear regression for the image SNR of a Synomag-D dilution series from 120 $\mathrm{\mu g_{Fe}}$ to 313 $\mathrm{\mu g_{Fe}}$ for each coil. **B** Dot phantom images of the dilution series and empty bore acquisitions. **C** Rendering of the G-phantom. **D** Reconstructed images of the G-phantom filled with 0.0313 $\mathrm{mg_{Fe}\,mL^{-1}}$ of Synomag-D.

IV. Conclusion

We designed and evaluated four receive coil inserts for NHP fMPI studies. The cylindrical gradiometer with a 14 cm diameter (Coil #2) achieved the highest sensitivity under the constraint of spatial fit. Larger ovoid coils offer flexibility to accommodate variability in NHP head sizes, albeit at the cost of reduced image SNR.

Acknowledgments

Funding was provided by the National Institute of Biomedical Imaging and Bioengineering (NIBIB), of the National Institutes of Health (NIH) under award numbers 5T32EB1680, U01EB025121, and NSF GRFP 1122374.

Author's statement

Conflict of interest: Authors state no conflict of interest.

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