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High Performance MPI with Magnetically induced Magnetosome Chains (MAGiCs)

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Abstract

In this study, we demonstrate the potential of magnetically induced magnetosome chains (MAGiCs), which are composed of biosynthesized magnetic nanoparticles (MNPs), as the tracers for magnetic particle imaging (MPI). The magnetosomes in MAGiC align in an orderly manner under the induction of a uniform magnetic field, and in this state, MAGiC can significantly enhance the MPI imaging quality. MPS result showed that compared to the commercial tracer VivoTrax+, MAGiC achieved a 25-fold improvement in resolution and a 91-fold increase in signal intensity. In 2D MPI, the reconstructed images achieved a resolution of 0.3 mm under a 1.25 T/m gradient field. All images were reconstructed using the x-space algorithm without employing iterative algorithms.

I. Introduction

Magnetic particle imaging (MPI) is a promising medical imaging modality that allows for quantitative imaging of the concentration distribution of magnetic nanoparticles (MNPs) [1]. The magnetic properties of MNPs directly determine imaging performance, such as resolution and sensitivity. However, there is currently no ideal tracer for MPI. In general, a balance needs to be struck among relaxation effects, saturation magnetization, and the steepness of the magnetization curve. Recent studies have shown that leveraging the interactions between MNPs can enhance the imaging performance of MPI. However, the superferromagnetic iron oxide nanoparticle chains proposed in earlier works can only exist in organic solvents, which has poor biocompatibility [2]. Magnetosomes synthesized by magnetotactic bacteria are Fe3O4 nanoparticles encapsulated in lipid membranes. The biogenically synthesized magnetosomes exhibit high biocompatibility [3].

II. Methods

In this study, we utilized an enhanced cultivation method to optimize the magnetic properties of magnetosomes, making them more suitable as tracers for MPI. Under the induction of a static magnetic field (80 mT for 5 s), magnetosomes can spontaneously organize into chain-like structures. We tested the magnetic properties of MAGiC on magnetic particle spectroscopy (MPS) and constructed a MPI system dedicated to MAGiC imaging with a gradient of 1.25 T/m. The excitation field is 40 mT@1kHz in both MPS and MPI. The x-space algorithm was used to reconstruct all images, without iterative algorithms. For more information on experiments and hardware, please refer to [4].

III. Results

MPS result (Figure 1) show that compared to the commercial tracer VivoTrax+, MAGiC achieved a 25-fold im-

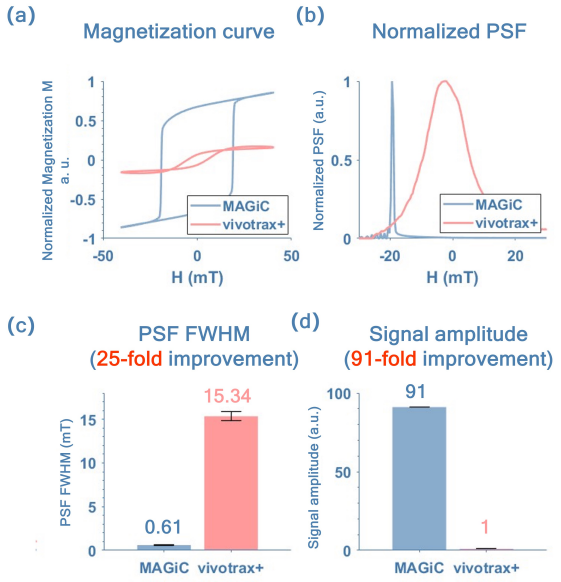

Figure 1: MPS results of MAGiC and VivoTrax+ at 0.1 mg Fe/mL. (a) M-H curves for MAGiC and VivoTrax+; (b) Normalized PSFs for MAGiC and VivoTrax+; (c) FWHM comparison between MAGiC and VivoTrax+; (d) Normalized signal amplitudes of MAGiC and VivoTrax+.

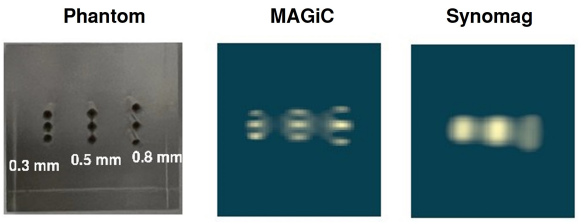

Figure 2: Reconstructed results of resolution phantom

provement in resolution and a 91-fold increase in signal intensity at 1 kHz, 40 mT excitation field. The excitation amplitude and frequency are different from those of conventional MPI parameters due to the unique properties of MAGiC. The excitation amplitude needs to be greater than the coercive field (approximately 20 mT) to fully magnetize MAGiC. Additionally, the larger magnetosomes (approximately 28 nm) in MAGiC require low-frequency excitation to minimize the effects of relaxation.

Figure 2 shows the imaging results of 2D MPI. The results indicate that, after gradient normalization, compared with synomag (using the Momentum system (Magnetic Insight) with a 5.7 T/m gradient), the MAGiC has a 20-fold improvement in resolution. For detailed results, please refer to [4].

IV. Conclusions

MAGiCs are composed of biomineralized magnetosomes. Under appropriate conditions, they exhibit exceptional MPI performance. MPS result showed that compared to the commercial tracer VivoTrax+, MAGiC achieved a 25-fold improvement in resolution and a 91-fold increase in signal intensity. In 2D MPI, the reconstructed images achieved a resolution of 0.3 mm under a 1.25 T/m gradient field.

Author's statement

Conflict of interest: Authors state no conflict of interest.

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