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A symmetric receive coil design for sentinel lymph node imaging

Haicheng Du[a,b] · Guanghui Li[a,b] · Ziwei Chen[a,b] · Yu An[a,b,*] · Jie Tian[a,b,c,*]

[a]Beijing Advanced Innovation Center for Big Data-Based Precision Medicine, School of Engineering Medicine,Beihang University, Beijing, China
[b]Key Laboratory of Big Data-Based Precision Medicine (Beihang University), Ministry of Industry and Information Technology of the People's Republic of China, Beijing, 100191, China
[c]CAS Key Laboratory of Molecular Imaging, Institute of Automation, Chinese Academy of Sciences, Beijing, China
[*]Corresponding author, email: yuan1989@buaa.edu.cn, tian@ieee.org

Abstract

Magnetic Particle Imaging (MPI) based sentinel lymph node detection provides a novel technical approach for investigating lymphatic metastasis and therapeutic response in tumors. However, current MPI systems mainly employ global receive coils, which exhibit limited spatial specificity and low local sensitivity. In this study, a dedicated positioning platform and a symmetric surface receive coil were designed for localized MPI of the inguinal lymph node in mouse applications, enabling stable animal fixation and precise anatomical alignment. Experimental results demonstrated that the proposed design achieved high local sensitivity for magnetic particle signal detection.

I. Introduction

The sentinel lymph node plays a vital role in studies of tumor lymphatic metastasis and therapeutic response in small-animal models [1]. The inguinal lymph node is a commonly used sentinel lymphoid tissue for observing breast tumor metastasis in mice. A typical application involves monitoring metastatic processes via plantar injection of superparamagnetic iron oxide nanoparticles (SPIONs) [2]. Accurate imaging of this region is essential for elucidating early metastatic mechanisms and assessing therapeutic efficacy. Magnetic Particle Imaging (MPI), as a novel tracer-based imaging modality, directly detects the nonlinear magnetization response of SPIONs. Its advantages include high temporal resolution, quantitative capability, and absence of background signal, which make it a promising technique for high-contrast, radiation-free lymphatic imaging and tumor metastasis monitoring.

However, conventional MPI systems predominantly use global receive coils, which suffer from insufficient sensitivity and poor spatial specificity for localized imaging of the inguinal region. To address these limitations, a symmetric high-sensitivity surface coil layout was developed, integrated with a dedicated mouse positioning platform, providing stable support and precise alignment of the inguinal region. This configuration effectively enhances local signal sensitivity and suppresses common-mode and direct feedthrough interference, offering a compact and general hardware solution for small-animal inguinal lymph node MPI detection.

II. Methods and materials

Based on the anatomical structure of the mouse and the position of the inguinal lymph node, a specialized MPI positioning platform with dimensions of

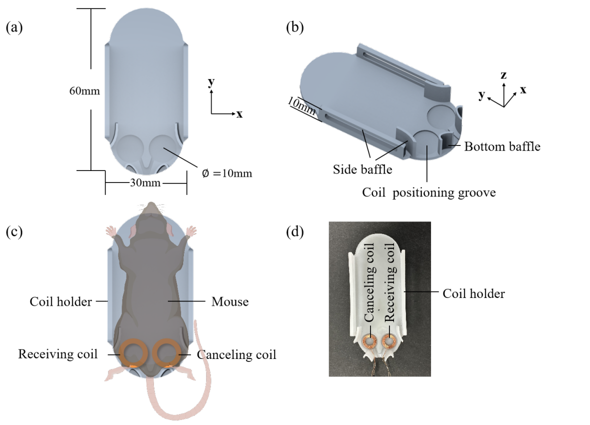

Figure 1: A specialized MPI positioning platform for the mouse model and symmetric surface coil layout. (a) Top view of the platform; (b) Side view rendering of the platform; (c) Schematic of mouse positioning and detection; (d) Picture of the assembled system.

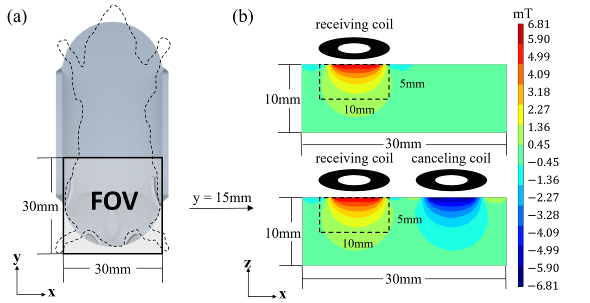

Figure 2: (a) Field of view (FOV) of the symmetric surface coil layout; (b) Comparative COMSOL simulations of the receive coil sensitivity on the plane y = 15 mm: the distribution without the canceling coil (top) and with the canceling coil (bottom).

60 mm × 30 mm × 10 mm was designed. The platform supports both the mouse and the symmetrically arranged receive and canceling coils. The platform was designed in SolidWorks and is publicly available at: https://github.com/BUAALGH/IWMPI-2026-Lymph-Coil

We designed canceling and receive coils with a symmetric layout, where the canceling coil and the receive coil were respectively placed at the symmetric positions of the inguinal lymph nodes on the left and right sides of the mouse. Both the receive and canceling coils share identical geometries: outer diameter 10 mm, inner diameter 6 mm. The coils were wound using 0.2 mm diameter copper wire, achieving an inductance of approximately 20 µH, and were connected in a differential configuration to effectively eliminate direct feedthrough.

Experiments were conducted using a self-developed open-sided Field Free Line MPI scanner[3]. Synomag-D (surface: plain, diameter: 70 nm) was used as the tracer material. Samples were prepared by serial dilution in phosphate-buffered saline (PBS). For each dilution, a 10 µL aliquot was measured. The prepared samples covered Fe masses ranging from 100 µg, 10 µg, and 1 µg, down to 500 ng, 200 ng, and 100 ng, respectively, with a blank background control included. For image reconstruction, the third-harmonic components of the measured voltage signals were extracted and analyzed. The reconstructed images were obtained using the filtered back projection algorithm.

III. Results and discussion

Figure 2 presents the COMSOL simulation results of the magnetic field sensitivity. The Z-component was analyzed to evaluate induction efficiency, as it aligns with the system's excitation direction. The upper subplot of Figure 2 (b) illustrates the field distribution without the canceling coil, while the lower subplot displays the differential configuration. The simulation results demonstrate that the receive coil provides a high-sensitivity field of view of approximately 10 mm × 5 mm, where the primary detection zone remains minimally affected by the canceling coil as its influence is predominantly confined to the peripheral regions.

As shown in Figure 3, experimental results indicate that 200 ng Fe can be detected by the proposed symmetric surface coil layout. 100 ng Fe is difficult to distinguish due to artifact interference. Therefore, the detection limit of this coil is estimated to be between 100 and 200 ng Fe.

To facilitate the transition to in vivo experiments, we plan to integrate a gas anesthesia system with the current specialized MPI positioning platform to ensure stable sedation. Furthermore, we will design a novel anatomically specific restraint module to suppress motion-induced artifacts caused by involuntary tremors. These measures are expected to significantly facilitate the effective execution of subsequent in vivo mouse experiments.

IV. Conclusion

A symmetric high-sensitivity surface receive coil integrated with a 3D-printed mouse positioning platform was developed for localized MPI detection of the inguinal lymph node in small-animal models. The system achieved high sensitivity in local magnetic particle signal detection, with a detection limit of approximately 200 ng Fe. Although currently limited to phantom studies, this compact hardware solution offers a promising technical approach for high-contrast lymphatic imaging. Future in vivo experiments will be conducted to further validate the imaging efficacy of the proposed device in biological settings.

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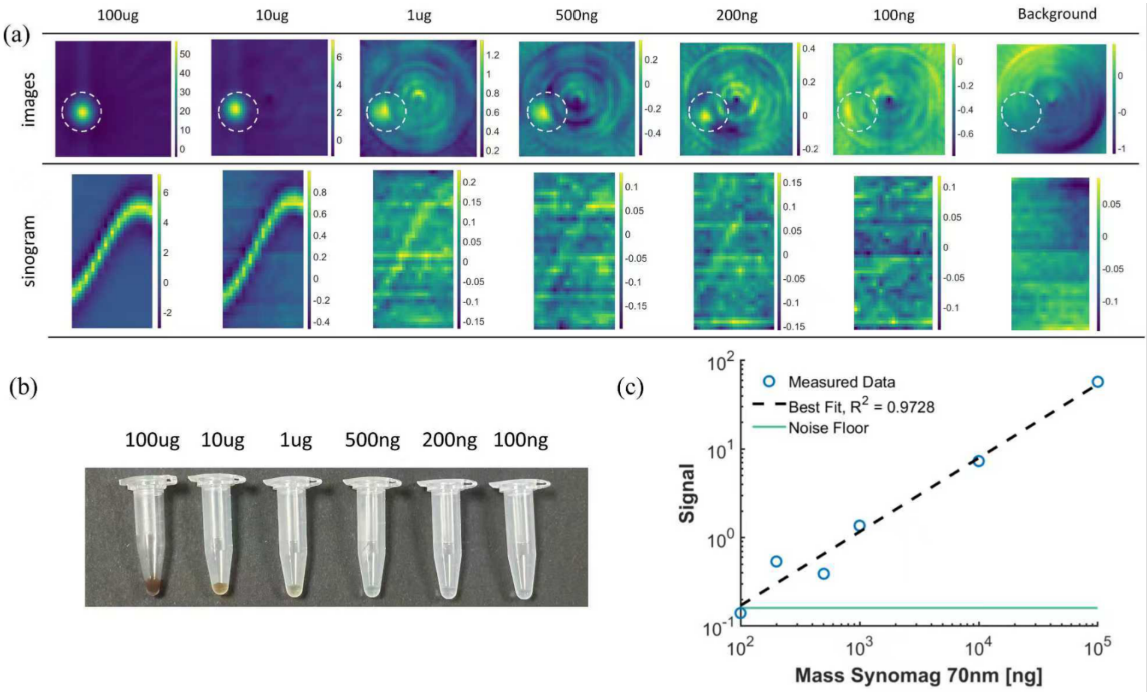

Figure 3: (a) MPI images of 10 µL point phantoms at varying iron masses. (b) Sample preparation: Synomag-D nanoparticle suspensions were diluted with PBS to a final volume of 10 µL for each target iron mass. (c) Relationship between the signal amplitude at the maximum-intensity pixel and iron mass.

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Author's statement

Conflict of interest: Authors state no conflict of interest. Haicheng Du and Guanghui Li contribute equally to this work.

References

[1] H. Kim, et al. Outcome of breast-conserving treatment for axillary lymph node metastasis from occult breast cancer with negative breast MRI. *The Breast.* vol. 49, pp. 63-69, 2020.

[2] G. Wang, et al. Sensitive and specific detection of breast cancer lymph node metastasis through dual-modality magnetic particle imaging and fluorescence molecular imaging: A preclinical evaluation. *European Journal of Nuclear Medicine and Molecular Imaging.* vol. 49, no. 8, pp. 2723-2734, 2022.

[3] J. He, et al. Sequential scan-based high-resolution 3-D open-sided magnetic particle imaging system. *IEEE Transactions on Instrumentation and Measurement.* vol. 73, pp. 1-12, 2024.

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