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Tomographic Imaging of Implanted Artificial Tumors in a Breast Phantom with a Single-Sided MPI Scanner

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Abstract
The conventional closed-bore MPI scanners restrict the imaging volume. A single-sided MPI scanner design allows for an unrestricted imaging volume, uniquely enabling the imaging of objects larger than those accommodated by commercially available MPI scanners. Here, we demonstrate our single-sided scanner's capabilities for potential breast cancer screening by imaging a large anatomical breast phantom.

I. Introduction

Breast cancer is one of the most commonly diagnosed cancers and one of the leading causes of cancer death among women worldwide [1], highlighting the need for improved early detection and diagnostic imaging techniques. MPI holds unique promise for breast cancer imaging by providing extremely high contrast detection of tumor-targeted SPIO tracers with zero background signal from surrounding tissue [2]. This results in unambiguous images that can identify even small or diffuse tumor masses and lesions. Our group has previously reported on a single-sided MPI prototype scanner capable of tomographic imaging [3]. Compared to conventional closed-bore MPI scanners, the unilateral geometry offers an unrestricted imaging volume suitable for larger subjects, such as animals or humans.

Our scanner employs field-free line (FFL) field configuration [4]. The FFL design offers advantages over field-free point (FFP) scanners [5–7], including higher sensitivity due to integration along FFL, and compatibility with well-established image reconstruction techniques such as filtered backprojection (FBP) [8].

Here, we demonstrate our scanner's capabilities by imaging a large (16 cm x 12 cm x 6 cm) anatomical breast phantom that exceeds the size limits of commercial small animal systems, targeting applications for breast cancer detection.

II. Methods and materials

In this work, our single-sided MPI scanner utilizes a 0.58 T/m gradient in field-free line (FFL) configuration and a 25 kHz excitation field with a 1.6 mT amplitude [9]. The scanner has stationary coils so to implement FBP imaging the subject is placed on a custom-built rotational table, which allows for mechanical rotation and height translation [3].

In the experiment, two samples of 18 μl spherical volumes filled with undiluted Synomag-D (Micromod, Germany) mimicking tumors were embedded 13 mm apart and 6 mm deep in the breast phantom (SynDaver, FL, USA) as shown in Fig.1. We performed FBP imaging in the coronal plane and 2D projection imaging in the axial plane at the maximum resolutions of 6 mm and 3 mm in the horizontal and vertical planes, respectively.

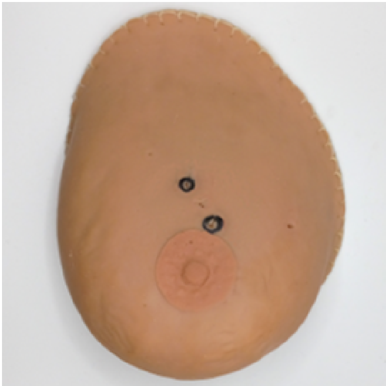

Figure 1: Anatomical breast phantom with two spots of implanted SPIO samples.

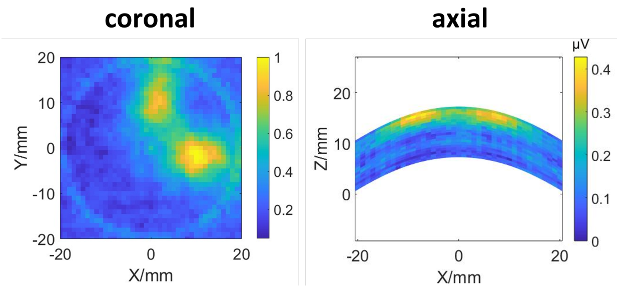

Figure 2: Experimental MPI images in coronal and axial planes of artificial SPIO tumors implanted in a breast phantom.

III. Results and discussion

The experimental imaging results are shown in Fig.2. The reconstructed FBP and projection images revealed distinct point sources with clear separation. Spatial resolution in the coronal plane, based on the point-spread function, was measured to be 6 mm full-width at half maximum, achieving sub-centimeter performance comparable to resolutions obtained by clinical nuclear medicine.

These results validate our single-sided MPI scanner's unique ability to image objects larger than those compatible with the existing commercial systems while maintaining an acceptable resolution. In the future, modifying the current setup with the scanner rotation will eliminate the need for a subject turntable thus lifting the limit on the overall subject size. This advancement opens new possibilities for applications requiring larger imaging volumes, particularly in clinical diagnostic imaging.

IV. Conclusion

In this work, we presented imaging in two orthogonal planes of embedded artificial tumors in a breast phantom with our single-sided FFL MPI scanner. The observed FWHM of the artificial tumors measured 6 mm in both the x- and y- directions and 3 mm in the z-direction, consistent with previously reported spatial resolution values at this imaging gradient 0.58 T/m [3]. Future work will include *in vivo* imaging of a breast tumor in a mouse model.

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Author's statement

Conflict of interest: Authors state no conflict of interest.

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