

Characterizing Suspicious Lesions with MR guided Diffuse Optical Breast Imaging

C. M. Carpenter^{1,2}, S. Jiang², S. P. Poplack³, R. M. diFlorio-Alexander³, B. W. Pogue², and K. D. Paulsen²

¹Radiation Oncology, Stanford University School of Medicine, Stanford, CA, United States, ²Thayer School of Engineering at Dartmouth, Hanover, NH, United States, ³Radiology, Dartmouth Hitchcock Medical Center, Lebanon, NH, United States

Background

Breast MR has high sensitivity, yet inclusion of other data sets could still lead to improved specificity [1]. To this end, an MR-guided optical breast imaging (MRg-OBI) was developed, validated through numerous phantom studies, as well as healthy volunteer and cancer subject exams [2, 3]. Optical imaging obtains spatial maps of disease-specific tissue properties such as total hemoglobin, oxygen saturation, water content, and tissue microstructure scatter, which have been shown in several studies to offer high specificity to malignant cancer [4]. This study examined the ability of MRg-OBI in characterizing malignant from benign lesions in five patients. The results show that total hemoglobin is a good indicator of malignancy, with tumor to background contrast varying greatly from 1.25 up to 8.0, compared to less than 1 for the benign/fully responded lesions.

Methods:

Optical data were acquired by measuring the light attenuation of 6 wavelengths in the near-infrared with 16 optical fibers placed in the coronal plane. These fibers were coupled to the breast tissue through a custom-built fiber interface which was integrated into a MR breast coil. This setup is shown in Figure 1. Optical images were acquired simultaneously during MR operation. Images of tissue properties were reconstructed with a model-based reconstruction algorithm. MR anatomical (T1-weighted) images were used to provide fiber locations and to guide the contrast in the optical image reconstruction through a structural weighting function[5]. Gadolinium contrast-enhanced (CE) MR images were acquired to define a region-of-interest, an area of suspect malignancy, which was characterized with optical imaging. This protocol was approved by the IRB at Dartmouth Hitchcock Medical Center.

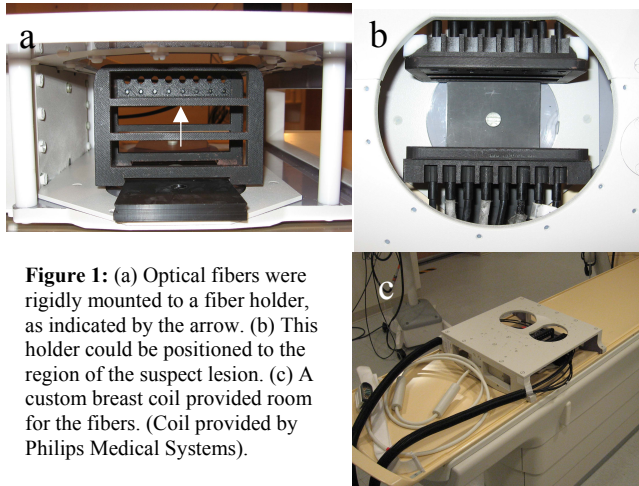


Figure 1: (a) Optical fibers were rigidly mounted to a fiber holder, as indicated by the arrow. (b) This holder could be positioned to the region of the suspect lesion. (c) A custom breast coil provided room for the fibers. (Coil provided by Philips Medical Systems).

Gadolinium contrast-enhanced (CE) MR images were acquired to define a region-of-interest, an area of suspect malignancy, which was characterized with optical imaging. This protocol was approved by the IRB at Dartmouth Hitchcock Medical Center.

Results:

Five women with abnormal mammograms or undergoing neoadjuvant chemotherapy treatment were imaged. Each woman was administered Gd (Magnevist, Bayer Healthcare, GER) via intravenous injection. High-resolution (0.7x0.7x1.5mm) 3D CE T1-weighted images (TR/TE/flip angle = 9/6/15) were acquired with a 3 Tesla MR magnet (Philips Achieva X) every minute. Three women with invasive ductal carcinomas, one with a fibroadenoma, and one who had fully responded to chemotherapy (as determined by pathology) were imaged. Example optical and MR images for a subject with invasive ductal carcinoma (IDC) are shown in Figure 2. Although no consistent trends were noted for oxygen saturation, water, or scatter (data not shown), there was a substantial separation between the healthy fibroglandular and the region of interest “tumor” region, shown in Figure 3. The shaded side of this figure represents patients with no/benign lesions, while the un-shaded side represents patients with invasive ductal carcinomas. The patients with no malignant lesions exhibited lower total hemoglobin in the region of interest than the fibroglandular background tissue. In contrast, the patients with malignant lesions exhibit at least a 25% increase in total hemoglobin in the region of interest compared to the background. This increase in hemoglobin can be explained by the increased vascular density and leaky vessels, which are inherent to malignant tumors.

Conclusions:

Five cases of suspicious breast lesions were investigated with MRg-OBI. Total hemoglobin images show a positive contrast between the lesion and the background in the cancer cases, while there is negative contrast in the non-malignant cases. This data shows the potential contrast for MRg-OBI is high in cancer tumors, and could add clinical information to MR breast exams.

Acknowledgements

This work was funded by NIH grant PO1CA080139, Philips Research Hamburg, and the DOD Pre-doctoral Training Fellowship 503298.

References:

- D. Bluemke, C. Gatsonis, M. Chen, G. DeAngelis, N. DeBruhl, S. Harms, S. Heywang-Kobrunner, N. Hylton, C. Kuhl, C. Lehman, E. Pisano, P. Causer, S. Schnitt, S. Smazal, C. Stelling, P. Weatherall, and M. Schnall, “Magnetic Resonance Imaging of the Breast Prior to Biopsy,” *JAMA-Journal of the American Medical Association* **292** (22), pp. (2004).
- B. Brooksby, B. W. Pogue, S. Jiang, H. Dehghani, S. Srinivasan, C. Kogel, T. Tosteson, J. B. Weaver, S. P. Poplack, and K. D. Paulsen, “Imaging Breast Adipose and Fibroglandular Tissue Molecular Signatures using Hybrid MRI-Guided Near-Infrared Spectral Tomography,” *Proc. Nat. Acad. Sci. USA* **103**, pp. 8828-8833 (2006).

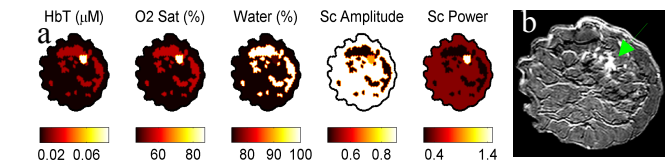


Figure 2: (a) MRg optical images for a patient with an invasive ductal carcinoma. Shown are images of total hemoglobin (HbT), oxygen saturation (O2 Sat), water, scatter amplitude, and scatter power. (b) Contrast-enhanced MR indicates a suspect region of interest.

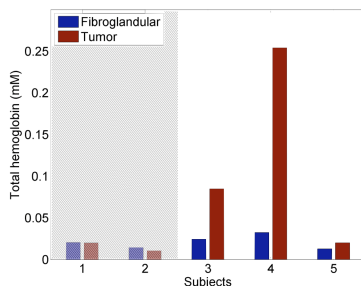


Figure 3: Comparison of suspected tumor vs. fibroglandular total hemoglobin for all subjects. The subjects in the non-shaded region had known malignant lesions. The shaded region consisted of a subject with a benign lesion and a subject who had fully responded to chemotherapy.

³B. Brooksby, S. Jiang, H. Dehghani, B. W. Pogue, K. D. Paulsen, C. Kogel, M. Doyle, J. B. Weaver, and S. P. Poplack, “Magnetic Resonance-Guided Near-Infrared Tomography of the Breast,” *Rev. Sci. Instr.* **75** (12), pp. 5262-5270 (2004).

⁴S. P. Poplack, T. D. Tosteson, W. A. Wells, B. W. Pogue, P. M. Meaney, A. Hartov, C. A. Kogel, S. K. Soho, J. J. Gibson, and K. D. Paulsen, “Electromagnetic Breast Imaging: Results of a Pilot Study in Women with Abnormal Mammograms,” *Radiology* **243** (2), pp. 350-9 (2007).

⁵H. Dehghani, B. W. Pogue, J. Shudong, B. Brooksby, and K. D. Paulsen, “Three-dimensional optical tomography: resolution in small-object imaging,” *Applied Optics* **42** (16), pp. 3117-28 (2003).