MR-Guided NIR Tomography to Determine Breast Cancer Malignancy

C. Carpenter[1], B. Pogue[1], S. Srinivasan[1], H. Dehghani[2], S. Jiang[1], K. Paulsen[1], C. Kogel[3], and S. Poplack[4]

[1]Thayer School of Engineering, Dartmouth College, Hanover, NH, United States, [2]Department of Physics, University of Exeter, Exeter, United Kingdom, [3]Dartmouth Hitchcock Medical Center, Hanover, NH, United States, [4]Radiology, Dartmouth Hitchcock Medical Center, Hanover, NH, United States

Problem: Because of the relatively low sensitivity of standard mammography in complex breast tissues, MRI has seen increasing use as a means to detect breast lesions. Breast MR has high sensitivity, yet suffers from comparatively low specificity. There is a need to develop new imaging methods that are sensitive to physiological parameters that will aid in characterizing areas within the breast MR image which show non-specific enhancement. Near infrared (NIR) spectral tomography has the advantage of obtaining spatial maps of key tissue properties such as total hemoglobin, oxygen saturation, water content, scatterer size, and scatterer density, while being non-invasive and non-ionizing. However, because of the highly scattering nature of tissue, spatial resolution in NIR imaging (~ 4-6mm) is quite limited. A dual modality MRI guided NIR spectroscopy instrument has been developed which can quantify these tumor metabolites with high spatial resolution.

Methods: MR-guided NIR was evaluated with simulations and phantoms to determine its success at distinguishing between areas of enhancement in an MR image. A case study of a patient with an infiltrating ductal carcinoma, invisible to non-contrast enhanced MR, is shown as an example of our ability to distinguish tumor physiological characteristics from the adipose and fibroglandular tissue. Increased total hemoglobin is expected in malignant tumors because of the leaky, more densely packed vasculature. This change in vasculature resulting from uncontrolled cellular multiplication may provide additional contrast in quantifying the size and density of organelles. Additionally, a decrease in hemoglobin oxygen saturation is also expected because of the increase in metabolism of malignant tumors. By transmitting near infrared light through the breast circumferentially, we are able to detect contrast in these parameters. Specifically, our MR-guided NIR instrument, introduced by Brooksby et al. [1,2], illuminates the breast with 6 wavelengths from fibers surrounding the breast in a single plane, from within the MR breast coil. The measurements are input into a finite element (FEM) algorithm which models the light propagation. An iterative inverse algorithm reconstructs spatial maps of the physiological parameters.

Results: A simulated case of a benign lesion mistaken as a malignant tumor in MR is shown in Figs 1,2. In this case, 1.5 cm malignant and benign lesions were added to a breast MR image obtained from a previous study. Noisy data (1%) was generated on this image, with typical physiological contrasts differentiating each tissue type. Fig. 1 shows the simulated MR image that has been segmented by tissue type, with MR defined tissues identified by color. The benign lesion (white) is positioned above the malignant lesion (white), surrounded by fibroglandular tissue (red), and adipose tissue (black). The results of reconstruction of the data are shown in Fig. 2b, compared to the truth in Fig. 2a. These results show an observable contrast between the benign and malignant lesions, with errors below ~ 10%. Fig. 3 shows the results of reconstructed data taken from a patient with a 1.1 cm tumor in the fiber plane. Increases in total hemoglobin and water content, and contrast in scatter, are observed which correlate well with the tumor location.

Conclusions: Additional contrast mechanisms that may help differentiate between malignant and benign tumors in the MR is a critical benefit to adding NIR tomography to MR breast exams. These examples demonstrate the potential of NIR tomography in distinguishing cancerous lesions. First, the simulation in Figs 1,2 show that this technique can be used to successfully detect differences in benign and malignant breast lesions. Fig. 3 shows the results of this technique applied to a patient with a malignant tumor, and the associated contrasts in the physiology. By additionally providing properties of adipose and fibroglandular tissue, information regarding the health of surrounding tissue may also be examined with this method. Future work for this project will involve identification of approaches to further compliment the MR exam with NIR information, and imaging of more tumor bearing patients.

References:
1. Brooksby, B., et al., Rev. Sci. Instr., 2004. **75**(12): p. 5262-5270.
2. Brooksby, B. et al., PNAS USA, 2006, 103(23): p. 8828-8833.

Figure 1. Simulated breast geometry segmented by region according to MR contrast, with outer adipose tissue (black), and inner fibroglandular tissue (red), with benign region (above) and malignant (below).

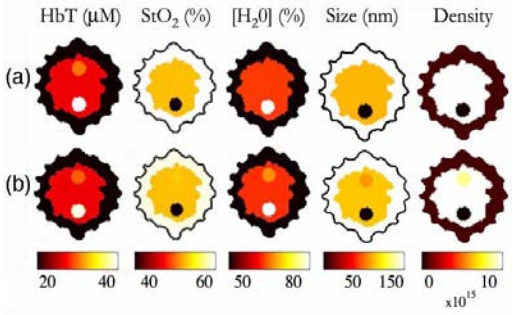

Figure 2 (a) Target physiological parameters with benign tumor located above malignant tumor **(b)** Reconstructed results

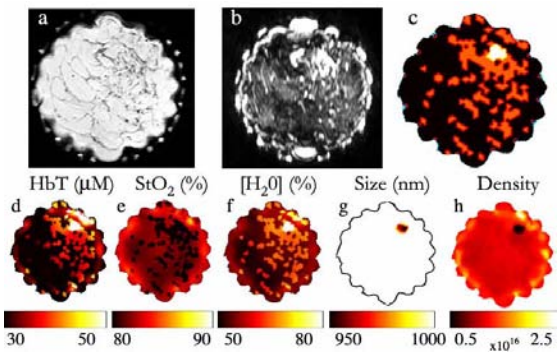

Figure 3 (a) T1 weighted and **(b)** Gd enhanced, coronal slice of a cancer bearing patient in plane of fibers **(c)** MR image segmented by tissue type **(d-h)** Functional NIR images