MRI-guided Near-Infrared Tomography Assessment of Breast Tissue Compostion</sup>

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Introduction

Near-Infrared (NIR) tomography can be readily combined with MR Imaging to provide the functional information of NIR spectroscopy with the high spatial resolution of MR. In this study, we implement a NIR tomography system designed for breast imaging, and couple it into the breast coil of a standard MR system. In this study, the boundary between fibroglandular and adiopose tissue was used to segment the MR image and enhance the image reconstruction of the NIR data sets. Absolute images of hemoglobin, oxygen saturation, water were recovered, as well as scattering images which yield the scatter density and average size within the tissue.

Materials and Methods

The system, as shown in Figure 1, consisted of 16 photomultiplier tubes for detection, 16 silica fiber optic bundles having 4 mm working diameter and a bank of 6 NIR laser diodes as frequency-domain light sources. Image reconstruction is completed with a finite element-based diffusion solver, which simulates NIR light propagation in tissue, which is then used for image formation through an iterative Newton-method based solver with a Levenberg-Marquardt type regularization procedure [1]. The absorption coefficients, μ_a, and elastic scattering coefficient, μ_s', images of the tissue are recovered, and given an assumption about the main absorbing chromophores being hemoglobin, oxy-hemoglobin and water in the NIR, the concentrations of each of these can be estimated throughout the tissue. Similarly, scattering coefficients, μ_s', are used to estimate the scatter amplitude and power, according the formula, $\mu_s'(\lambda) = a\,\lambda^{-b}$, where a is the amplitude and b is the power, and λ is wavelength [2, 3]. Several calibration studies were completed [4]. Six normal human subjects were recruited for this study, and imaged in the combined system. All subjects gave informed consent to participate, and the study was approved by the institutional IRB.

Results

Images of hemoglobin, oxygen saturation, and water were recovered from each subject, after segmenting the tissue along the lines of the gray-scale difference of adipose and glandular regions. The NIR image reconstruction was completed with a customized regularization parameter difference between these two tissues, and linking them in a way such that pixels within a given tissue type all had the same level of regularization. Representative resulting figures are shown below in Figure 2. This procedure was completed on six subjects, and a data set summarizing the mean and standard deviation of each of these absorbers is shown at right in Figure 2. This data shows the hemoglobin, oxygen saturation, and water values for both the adipose and the fibro-glandular tissues structures.

Discussion

The data shows that total hemoglobin in adipose (fat) tissue is near 10 microMolar average value, with an observed standard deviation of 7 microMolar, whereas in the fibroglandular tissue, the value is 21 microMolar, with a variance of 9 microMolar. The oxygen saturation of the hemoglobin was 62% in the adipose region, and 75% in the glandular. The water content observed was 55% in the adipose regions and 85% in the glandular regions. These are perhaps the most accurate estimates of breast tissue composition taken with NIR tomography, due to the ability of separation of the tissue types through combination with T1-weighted MR imaging.

Figure 1. Photographs of the source-detection system are shown at far left, and in the middle the fiber optic array coupled into the breast coil are shown. In the far right, a patient is positioned on the breast coil with fiber array in place for simultaneous MRI-NIR imaging.

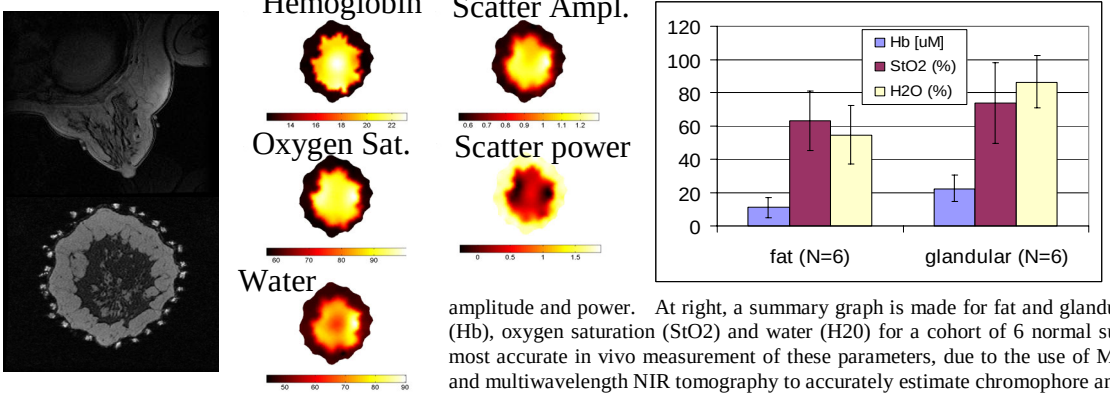

Figure 2. At far left, a T1 image of a breast is shown in both sagittal and coronal views. In the middle set of images, coronal tomographic images of the NIR parameters reconstructed are shown, using the coronal MRI as guidance. These images include hemoglobin concentration (microMolar), oxygen saturation (%), water fraction (%), NIR scattering amplitude and power. At right, a summary graph is made for fat and glandular tissue values for hemoglobin (Hb), oxygen saturation (StO2) and water (H20) for a cohort of 6 normal subjects. This data represents the most accurate in vivo measurement of these parameters, due to the use of MRI to guide the tissue boundary, and multiwavelength NIR tomography to accurately estimate chromophore and scatterer concentrations.

References

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