BOLD imaging of compressed breast hemodynamics

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ABSTRACT Time-resolved hemodynamic changes in the breast resulting from the application of external compression have recently been investigated as potential biomarkers of breast cancer [1]. Using high time-resolution near-infrared diffuse optical spectroscopy to monitor post-compression hemodynamics, our group was able to demonstrate the non-invasive estimation of breast tissue blood flow and oxygen consumption [2,3]. Encouraged by these results, we have designed an integrated MRI-optical breast compression platform that will enable simultaneous acquisition of MR and optical images. MR scans can provide structural information to enhance the optical reconstructions, as well as dynamic blood oxygen level dependent (BOLD) images sensitive to deoxy-hemoglobin (HbR) concentration for cross-validation against optically measured HbR values. In this submission we describe the MRI breast compression platform and initial results from dynamic MRI scans of the compressed breast, indicating contrast between the BOLD signal time-course in fibro-glandular vs. adipose tissue.

MATERIALS AND METHODS Figure 1 shows two photographs of the MR breast compression platform consisting of a parallel plate acrylic frame and an 8-element receive phased array mounted on sagitally oriented compression plates actuated hydraulically. Five healthy volunteers were recruited and a set of 3-5 2-minute compressions were performed on each, dynamically imaging each volunteer's left breast before and during the compression. 16-25 sagittal slices were obtained using an EPI sequence (fat. sat., TR/TE/α=2500/31/90 ms/ms/°, 64x64 image matrix, 12x12 cm FOV, 1.875 mm square pixels).

RESULTS AND DISCUSSION Figure 2 shows an example compressed breast slice from a 26-year old volunteer. Saturation regions were used to suppress signal from the chest and allow better breast spatial resolution. Figure 3 a)-c) shows the post-compression time-course of the image intensity from 3 regions of interest chosen from areas of a) apparent fibro-glandular tissue, b) apparent adipose tissue, and c) the image background (to monitor scanner stability). The identification of tissue type was based on the image intensity, as in a fat-suppressed scan the water-rich fibro-glandular tissue is expected to appear bright. Images are normalized to the maximum pixel value in the entire slice series. The fibroglandular ROI signal increases by ~7.5% of its corresponding ROI mean over the measurement time-period, the adipose ROI signal decreases by ~15% of the ROI mean during the same period, and finally, the image background shows a small amount of noise with no obvious trend. Since the image noise is significantly lower than the ROI signal changes, these changes are likely real and probably caused by a decrease in the concentration of deoxy-hemoglobin (HbR) in the glandular area, and an increase in HbR in the adipose region. Previous studies [2,3] have shown that once the compression plates have finished their motion and remain stationary, tissue visco-elastic relaxation leads to a reduction in compression pressure. Consequently, a possible explanation for the observed trends is that the adipose area is in equilibrium with the reducing external pressure and is now experiencing blood return, thus increased HbR concentration. At the same time, the glandular tissue, which is stiffer and has higher extra-cellular matrix fluid viscosity, has not yet equilibrated with the external pressure and is still allowing a reduction in blood volume (decreasing HbR) – note the time-course appears to reach a plateau at the end of the scan and a longer measurement would probably show the signal beginning to decrease as the glandular tissue begins to relax, as in the case of the adipose ROI. The integration of optical imaging will allow us to cross-validate these observations between the modalities.

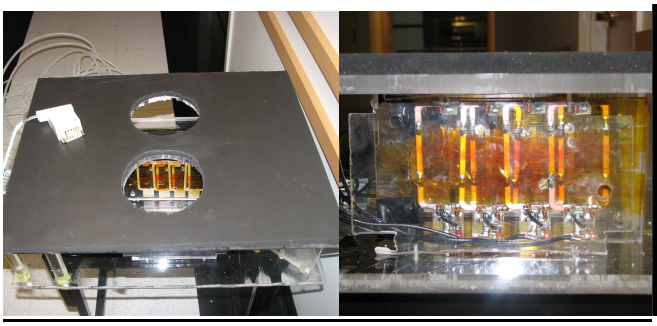


Figure 1. MR breast compression platform

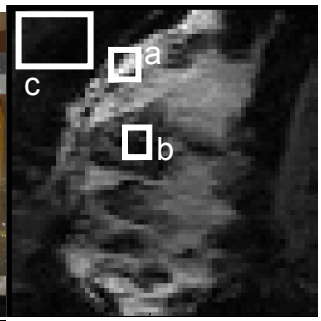
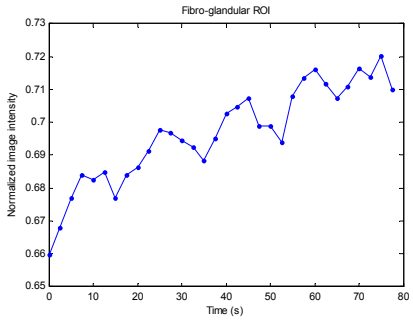
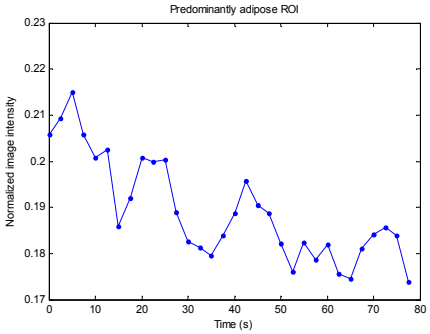


Figure 2. Compressed breast sagittal GE-EPI slice; **Figure 3a)** BOLD time course in fibro-glandular area





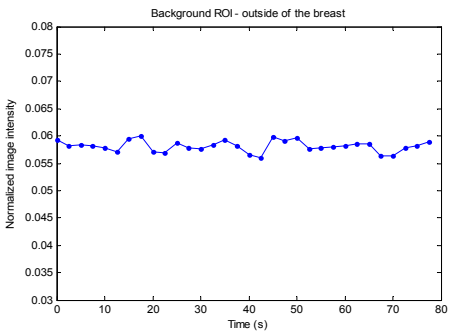


Figure 3b) BOLD time course in predominantly adipose area; **3c)** BOLD time course in image background

References
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2. Carp et al., J. Biomed. Opt., 11, Art. 064016 (2006).
3. Carp et al., Opt. Expr., 16, p 16064-16078 (2008).