Coregistration of Contrast Enhanced MRI and Broadband Diffuse Optical Spectroscopy for Characterizing Breast Cancer

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Purpose

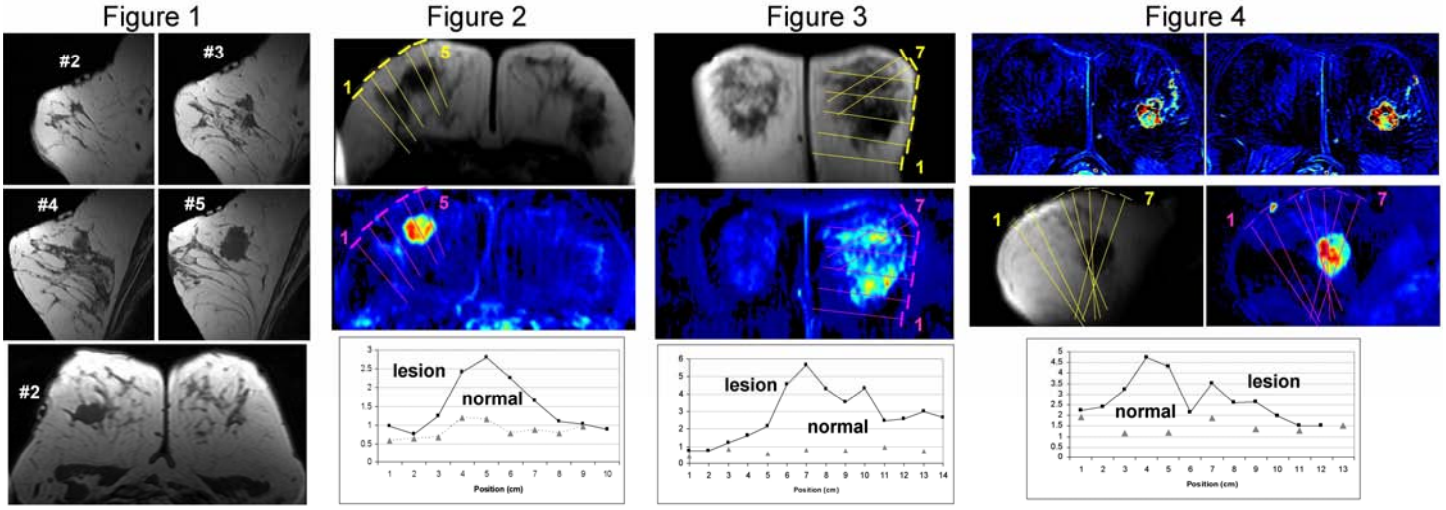
In recent years DCE-MRI has evolved into a standard clinical breast imaging modality. It is often performed to aid in diagnosis in case of equivocal findings in mammogram or ultrasound. Due to its high sensitivity it is also performed for pre-operative surgical planning and screening of young women at high risk of developing breast cancer. However, it is known that MRI detects many benign lesions that may lead to unnecessary biopsy or over-treatment. Diffuse Optical Spectroscopy (DOS) is a non-invasive optical technique that employs near-infrared (NIR) light to characterize the optical properties of tissues quantitatively. It can measure the concentration of water, lipid, and oxy-, deoxy-hemoglobin, which may provide complementary information to better characterize lesions found in breast tissue. In this study we performed sequential DOS and DCE_MRI studies using external fiducial markers for co-registration. The 3D MRI was re-sliced to obtain the DOS scan plane. A tissue optical index combining water, lipid and deoxy-hemoglobin concentration along the DOS scan line was correlated with MRI enhancement patterns.

Methods

Six patients (31-56 years old) with histological-proven breast cancer were studied. The patient received a DOS study using a broadband laser breast scanner with a hand-held probe containing avalanche photodiode, source and detector fibers. The system combines frequency-domain photon migration (FDPM) with steady-state (SS) tissue spectroscopy to measure NIR absorption and scattering of breast tissues *in vivo*. After the lesion was located, DOS measurements were made by moving the probe to discrete locations along a line at 1.0 cm intervals to form a linescan across the lesion and surrounding normal tissue. From the absorption spectrum quantitative concentration measurements of oxy-hemoglobin (Hb-R), deoxy-hemoglobin (Hb-O_2), water, and lipid were calculated. A lesion is expected to have high water, low lipid, and a high deoxy-hemoglobin concentration, thus an optimized tissue optical index (TOI, defined as the [Hb-R][water]/[lipid]) was calculated to characterize the lesion. A symmetric scan was performed in the contralateral normal breast. After the DOS study, fiducial markers (1.4 cm disk with a hollow center, which appears bright on T1-weighted MR images) were placed on every other scan sites, then the patient was sent to MRI study. MRI protocol included sagittal view pre-contrast sequence from the concerned breast, and an axial view bilateral dynamic contrast enhanced sequence. Figure 1 shows the T1-weighted images with markers visible on the skin surface, #2-5 on 4 different sagittal slices, and #2 on one axial slice. The hollow center in each marker was clearly visible. These markers were used as a visual guide in re-slicing the 3D dynamic MRI images along the DOS scan line. The original 32-slices of DCE-MRI were first converted into volumetric image matrices with isotropic voxels to facilitate re-slicing in any plane. The locations of fiducial markers were manually outlined and then converted into the same sized volumetric matrix. Then the marker images were projected into 3 orthogonal projection planes in axial, coronal and sagittal orientations, respectively. The plane that showed the highest number of markers was chosen to select the re-slicing plane according the line through the center of markers (i.e. the DOS scan line). After the tangential plane through the DOS linescan was obtained, the transverse plane perpendicular to the DOS linescan at each marker location was then determined. This slice represented the tissue volume covered under each individual DOS measurement site.

Results

Figures 2-4 illustrate 3 cases, a circumscribed mass, an inflammatory cancer with septal enhancements, and a mass with a necrotic center. Fig 2 shows the re-sliced MRI along the DOS scan line, from the original images shown in Fig.1. The location of the 5 fiducial markers is marked as a short segment on the skin surface, and the perpendicular line shows the transverse plane covered under each marker. The enhanced lesion was covered under the markers #4 and #5, as shown on the color-coded enhancement maps. The TOI at 10 scan sites from the lesion and from the symmetric location in the contralateral breast are shown. A sharp TOI peak was found corresponding to the mass (Fig. 2). A broadened TOI peak was observed for a patient with a diffuse lesion. In Fig.3, an inflammatory cancer with septal pattern showed two TOI peaks that correlated qualitatively with the 2 MRI enhancement areas. In Fig.4, a dip in TOI peak was found corresponding to a lesion with a necrotic center. Overall, the TOI peak width was not correlated with the size of lesion, and the % MRI enhancement was not correlated with the total hemoglobin concentration.



Discussion

In this study we correlated the findings from DCE-MRI and DOS studies from the same patients. In general the TOI peak correlated with the morphological pattern of the enhanced lesions. No peak was found from the normal breast tissues in the contralateral side. A sharp TOI peak was found in 3 cases with a well-circumscribed mass, a broader peak was found in 2 cases with diffuse pattern, and a TOI dip was found in one case with a necrotic center. MRI clearly has superior spatial resolution to DOS and this feature can be used to guide optical tomographic reconstruction schemes. Since DOS measures diffuse optical properties, it is not a good morphologic imaging modality to measure size. On the other hand, DOS can also provide information which is not available in MRI, such as absolute hemoglobin concentrations and tumor hemoglobin oxygen saturation, thus DOS may provide complementary functional information to improve diagnostic specificity of MRI.

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